Carnegie Institution

OF

Washington

YEAR BOOK No. 19

1920

CARNEGIE INSTITUTION

OF

WASHINGTON

YEAR BOOK No. 19

1920

PUBLISHED BY THE INSTITUTION
WASHINGTON, U. S. A.
January 1921

PRESS OF GIBSON BROS., INC.
WASHINGTON, D. C.

LIST OF PRESENT AND FORMER TRUSTEES.

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904:

The President of the United States.
The President of the Senate.
The Speaker of the House of Representatives.
The Secretary of the Smithsonian Institution.
The President of the National Academy of Sciences.

OFFICERS FOR THE YEAR 1920.

ASSOCIATES OF THE INSTITUTION.

DIRECTORS OF DEPARTMENTS OF RESEARCH.

Louis A. Bauer, Department of Terrestrial Magnetism.
Francis G. Benedict, Nutrition Laboratory.
Benjamin Boss, Department of Meridian Astrometry.
Charles B. Davenport, Department of Experimental Evolution.
Arthur L. Day. Geophysical Laboratory.
George E. Hale, Mount Wilson Observatory.
J. Franklin Jameson, Department of Historical Research.
Daniel T. MacDougal, Department of Botanical Research.
Alfred G. Mayor, Department of Marine Biology.
George L. Streeter, Department of Embryology.

INVESTIGATORS PRIMARILY CONNECTED WITH THE INSTITUTION.

*William Churchill, Associate in Primitive Philology.
Frederic E. Clements, Associate in Ecology.
Oliver P. Hay, Associate in Paleontology.
Elias A. Lowe, Associate in Paleography.
Sylvanus G. Morley, Associate in Mid-American Archeology.
George Sarton, Associate in the History of Science.
Esther B. Van Deman, Associate in Roman Archeology.
George R. Wieland, Associate in Paleontology.

OTHER INVESTIGATORS.

Carl Barus (Brown University), Research Associate in Physics.
John S. Bassett (Smith College), Research Associate of the Department of Historical Research.
Henry Bergen, Research Associate in Early English Literature.
V. Bjerknes (University of Bergen, Norway), Research Associate in Meteorology.
E. C. Case (University of Michigan), Research Associate in Paleontology.
W. E. Castle (Harvard University), Research Associate in Biology.
T. C. Chamberlin (University of Chicago), Research Associate in Geology.
B. M. Duggar (Missouri Botanical Garden), Research Associate of the Department of Botanical Research.
H. D. Fish (Denison University), Research Associate of Department of Experimental Evolution.
Dixon R. Fox (Columbia University), Research Associate in History.
E. E. Free, Research Associate of the Department of Botanical Research.
J. C. W. Frazer (Johns Hopkins University), Research Associate in Chemistry.
J. W. E. Glattfeld (University of Chicago), Research Associate of the Department of Botanical Research.
John F. Hayford (Northwestern University), Research Associate in Physics.
Henry M. Howe (Columbia University), Research Associate in Metallurgy.
Marcus W. Jernegan (University of Chicago), Research Associate of the Department of Historical Research.
J. C. Kapteyn (University of Groningen), Research Associate of the Mount Wilson Observatory.
C. C. Little (Harvard University), Research Associate of Department of Experimental Evolution.
Albert Mann, Research Associate in Biology.
L. B. Mendel (Yale University), Research Associate in Physiological Chemistry.
A. A. Michelson (University of Chicago), Research Associate of the Mount Wilson Observatory.
T. H. Morgan (Columbia University), Research Associate in Biology.
Frank Morley (Johns Hopkins University), Research Associate in Mathematics.
*H. N. Morse (Johns Hopkins University), Research Associate in Chemistry.
F. R. Moulton (University of Chicago), Research Associate in Mathematical Physics.
E. L. Nichols (Cornell University), Research Associate in Physics.
A. A. Noyes (California Institute of Technology), Research Associate in Chemistry.
Thomas B. Osborne (Connecticut Agricultural Experiment Station), Research Associate in Physiological Chemistry.
T. W. Richards (Harvard University), Research Associate in Chemistry.
H. C. Sherman (Columbia University), Research Associate in Chemistry.
Frederick Slocum (Brown University), Research Associate of the Department of Terrestrial Magnetism.
John S. P. Tatlock (Leland Stanford Junior University), Research Associate in Literature.

*Died June 9, 1920. †Died August 8, 1920.

CONTENTS.

ORGANIZATION, PLAN AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

ARTICLES OF INCORPORATION.

Public No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be in enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

Sec. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

Sec. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

Sec. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

Sec. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

Sec. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corpora-

tion hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

Article VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

Article VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

NINETEENTH, TWENTIETH, AND TWENTY-FIRST MEETINGS OF THE BOARD OF TRUSTEES

ABSTRACTS OF MINUTES OF THE NINETEENTH, TWENTIETH, AND TWENTY-FIRST MEETINGS OF THE BOARD OF TRUSTEES.

NINETEENTH MEETING.

An adjourned meeting was held in Washington in the Board Room of the Administration Building on Saturday, January 24, 1920, and was called to order at 10 a. m. by the Chairman, Mr. Root.

Upon roll-call the following Trustees responded: Robert S. Brookings, John J. Carty, Charles L. Hutchinson, Andrew J. Montague, William W. Morrow, James Parmelee, Wm. Barclay Parsons, Stewart Paton, Elihu Root, Martin A. Ryerson, Theobald Smith, Charles D. Walcott, Henry P. Walcott, William H. Welch, Henry White, Robert S. Woodward.

The minutes of the eighteenth meeting were approved as printed and submitted to the members of the Board.

Mr. W. Cameron Forbes of Massachusetts was elected a Trustee of the Institution to fill the vacancy in the Board caused by the death of Mr. Henry L. Higginson.

The Secretary reported another vacancy in the Board as a result of the resignation of Mr. George Wharton Pepper.

The meeting adjourned at $12^h 20^m$ p. m. with the understanding that another special meeting of the Board might subsequently be called by the Chairman.

TWENTIETH MEETING.

Upon call of the Executive Committee, a special meeting was held in Washington in the Board Room of the Administration Building on Tuesday, May 25, 1920, and was called to order at $10^h 15^m$ a. m. by the Chairman, Mr. Root.

Upon roll-call the following Trustees responded: Robert S. Brookings, W. Cameron Forbes, Myron T. Herrick, Henry Cabot Lodge, William W. Morrow, James Parmelee, Wm. Barclay Parsons, Stewart Paton, Elihu Root, Theobald Smith, Charles D. Walcott, William H. Welch, Henry White, George W. Wickersham, Robert S. Woodward.

Upon recommendation of the Executive Committee, Dr. John C. Merriam of the University of California was unani-

mously elected to the presidency of the Institution. It was the understanding that Dr. Merriam would enter the service of the Institution on July 1, 1920, although he would not assume active direction as President until the retirement of Dr. Woodward on December 31, 1920.

The meeting adjourned at $10^h\ 45^m$ a. m.

Twenty-First Meeting.

The meeting was held in Washington in the Board Room of the Administration Building on Friday, December 10, 1920, and was called to order at 10 a. m. by the Chairman, Mr. Root.

Upon roll-call the following Trustees responded: Robert S. Brookings, John J. Carty, Cleveland H. Dodge, Charles P. Fenner, W. Cameron Forbes, Myron T. Herrick, Charles L. Hutchinson, Henry Cabot Lodge, Andrew J. Montague, William W. Morrow, James Parmelee, Wm. Barclay Parsons, Stewart Paton, Henry S. Pritchett, Elihu Root, Martin A. Ryerson, Theobald Smith, Charles D. Walcott, Henry P. Walcott, William H. Welch, Henry White, George W. Wickersham, Robert S. Woodward.

Upon invitation, the President-elect of the Institution, Dr. John C. Merriam, was also present.

The minutes of the meetings of January 24 and May 25, 1920, were approved as printed and submitted to the members of the Board.

The reports of the President, the Executive Committee, the Auditor, the Finance Committee, Directors of Departments, Associates and Research Associates of the Institution were then considered.

The following appropriations for the year 1921 were authorized:

Insurance Fund	$25,000
Pension Fund	40,000
Administration	55,000
Publication (including Division of Publications)	85,000
Departments of Research	966,162
Associates of the Institution	22,800
Minor Grants	98,600
Index Medicus	17,500
Total	1,310,062

Mr. Herbert C. Hoover of California was elected a Trustee of the Institution to fill the vacancy in the Board caused by the resignation of Mr. George Wharton Pepper.

Mr. Charles D. Walcott and Mr. Henry White were reelected members of the Executive Committee for a period of three years.

The organization of a Department of Genetics of the Institution was authorized, to date from January 1, 1921, with the understanding that the Department of Experimental Evolution and the Eugenics Record Office will become sections of this new department.

Provision was authorized for the appointment of an Administrative Secretary of the Institution to be nominated by the President and whose duty it shall be to assist the President in the executive administration.

The meeting adjourned at 11^{h} 50^{m} a. m.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1920

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1920, along with provisional recommendations of appropriations for the ensuing year.

This report is the nineteenth annual administrative report of the Institution and is presented under the following principal heads:

1. Historical notes.
2. Researches of the year.
3. Financial records.
4. Publications of the year.
5. Bibliographical appendix.

HISTORICAL NOTES.

Obituary Notices.

The impersonal and the majestic procedure of the processes of evolution, which it is the special object of the Institution to observe, to record, and to correlate, has again been made impressive during the past year by the death of a Trustee, Henry Lee Higginson, and by the deaths of two associate investigators, William Churchill and Harmon Northrop Morse. The passing of these colleagues and contemporaries serves to remind us at the same time of their

distinguished services in altruistic endeavors and of the relatively narrow limits of time and of opportunity available to the individual for application of his more mature capacities. Something like the first third of life is spent by the average man in finding himself; a second third is consumed in testing his abilities and in establishing a reputation for trustworthiness; while a scant remaining third, in general, permits the pursuit of highest usefulness to his race.

Henry Lee Higginson was born in New York City, November 18, 1834, but he lived nearly all his life in Boston, where he died November 14, 1919. He was one of the initial Trustees of the Institution and maintained a keen interest in its affairs to the day of his death. On this date, in fact, and but a few hours before death, he sent a letter to the Institution extending greetings to his colleagues but expressing fear that he might not be able to attend the annual meeting of the Board of Trustees to be held a month later. Like Dr. Billings and Dr. Mitchell of the initial group of Trustees, Higginson was a well-known veteran of the Civil War, in which he attained the rank of lieutenant-colonel and in which he was severely wounded. He was by nature a somewhat aggressive man, as related in the remarkable autobiography of his friend Henry Adams, and elsewhere; but no one could wish for a fairer or more generous antagonist. Whatever cause he espoused he urged and supported with the utmost vigor and sincerity. There was never any doubt about his conviction concerning any question to which he gave attention. He was passionately devoted to the promotion of education and to the cultivation of the higher types of music. His services as a member of that corporate body known as the "President and Fellows of Harvard College" and his long maintenance of the Boston Symphony Orchestra entitle him to grateful appreciation from his contemporaries and still more from their successors.

Mr. Higginson was a regular attendant at the meetings of the Board of Trustees of the Institution and he served as a member of the Finance Committee from 1902 to 1913. With regard to financial affairs he was a bold optimist and did not hesitate to urge action in defiance of the laws of probability and the perils

of bankruptcy. He often used to say that the object of the Institution is to spend funds, not to conserve them. Thus he consistently opposed the establishment of the Insurance and the Reserve Funds of the Institution. He was so serenely confident in the altruistic merits of its work that he saw no dangers even in attempts to capitalize deficits. But he was equally serene in the defeats he encountered in debates with his colleagues and was always generously willing to concede that his judgment might be at fault. His robust honesty, his obvious sincerity, his zeal in all progressive enterprises, and his willingness to work unceasingly for the public weal made him a national figure as well as one of the first citizens of the Commonwealth of Massachusetts.

William Churchill, Associate of the Institution in primitive philology since 1915, was born in Brooklyn, New York, October 5, 1859, and died at the Garfield Hospital, Washington, District of Columbia, June 9, 1920. While yet an undergraduate at Yale University, from which he received the degree of bachelor of arts in 1882, he began the arduous linguistic studies whose later extension made him one of the leading experts of America in philology. After a somewhat varied career, chiefly in the Government service, including the positions of consul-general at Samoa and at Tonga, he became one of the editors of the New York Sun, serving continuously in this capacity from 1902 to 1915. But while this connection with a great metropolitan journal served as a vocation, his linguistic avocation was pursued unceasingly, though in comparative obscurity even to the leading experts in contemporary philology. His field of research was the Polynesian languages. With surprising numbers of these he had become intimately acquainted during his sojourn in the Pacific Islands. He had not only made penetrating studies of these languages, but he had also made equally important anthropological investigations of the races of men who had developed and dispersed these languages. He was thus what the dominant part of the intellectual world still calls, but quite inappropriately, a "narrow specialist," when the attention of the Institution was directed to his talents, in 1905, by some of his friends. A visit to his library and an examination of his manuscripts and methods of work revealed, even to a "narrow specialist" in

quite another field, a man of remarkable capacities and accomplishments. He turned out to be one of the very rare instances of "exceptional men" not in plain sight. But the reason for his obscurity was immediately evident and required only a suggestion for its speedy elimination.

It was not until ten years later, however, that Mr. Churchill became directly connected with the Institution. In the meantime four volumes of publications from his pen had been issued by the Institution, when he was made an Associate with the expectation that all his time and talents could be devoted to his chosen field. He was well started in this when the world war deflected his activities into governmental channels and possibly sapped his vitality in a degree of overwork to which he had been long accustomed to yield on the slightest solicitation.

Mr. Churchill afforded a striking illustration of the maxim often verified in the history of the Institution, "that the training of a specialist must be broadly liberal in order that it may be minutely special." Thus he was an uncommonly well-read man in science, history, and general literature as well as in philology. His long experience as an editor gave him also a comprehensive world view of men and affairs. Few men are so ready with knowledge as he was and few more generous in placing it at the disposal of others. When, for example, an attempt was made, in 1910, to arrive at a consensus of opinion concerning the "humanities" by addressing a circular letter to about fifty experts in that field, Mr. Churchill was one of this number. He not only took the request seriously, but examined it at length, historically, statistically, and intrinsically as it affects the Institution. He took the trouble laboriously to classify and to count up the pagination of the works already published by the Institution, and it appears but just to say that his contribution to this symposium is at once the most objective and the most constructive of a remarkable collection of voluntary testimony concerning a controversial subject of unusual interest in the fields of scholarship.

Harmon Northrop Morse was born at Cambridge, Vermont, October 15, 1848, and died at his summer home on Great Chabeague Island, Casco Bay, Maine, August 8, 1920. He was a graduate of Amherst College of the class of 1873, attained the

degree of doctor of philosophy at the University of Göttingen in 1875, and joined the staff of the department of chemistry in Johns Hopkins University soon after its establishment in 1876. He continued in this capacity until the end of his life, although he retired from active service in the University in 1916. During all this time he was known chiefly as an investigator rather than as a teacher. His connection with the Institution as a Research Associate began in 1902.

The life work of Professor Morse illustrates in a striking degree how intricate, if not stubborn, are the properties of matter; how painfully slowly progress may be expected, in general, to proceed; and, hence, how important it is to maintain agencies which may insure continuity of support for patient and persistent efforts. The principal research which Professor Morse set for himself, and in which he achieved marked success, lies in the domain of molecular physics. The doctrine of the atomicity of matter is as old as the philosopher Democritus and the poet Lucretius. But little advance toward quantitative knowledge in this domain was made before the advent of the fruitful hypotheses and experiments of Dalton, Avogadro, Ampère, and Gay-Lussac, who were active during the first half of the nineteenth century. The restricted field of this extensive domain cultivated by Professor Morse is that known as osmotic pressure, which is developed by the flow or migration of the molecular elements of solutions through a membrane separating them. Precise measurements of this pressure in any case require elaborate apparatus and great care in all details of manipulation; but the thing most essential is a membrane, or sieve, of the requisite fineness and uniformity. This adjunct proved to be a porous earthenware cup, but its successful development consumed about a decade of time and baffling effort. Comparatively few men would have persisted in such a task. All obstacles were overcome, however, and the results of the researches were ready for publication in time for submission to the Turin Academy of Sciences, which offered an award on the occasion of the celebration of the hundredth anniversary of Avogadro's promulgation of his hypothesis, namely, that equal volumes of different gases, subject to the same pressures and same temperatures, contain

equal numbers of molecules. In announcing the receipt of this award, Professor Morse sent the following characteristic letter to the Institution, under date of February 29, 1912:

"I have just received from the Accademia Delle Scienze di Torino the announcement that the medal provided for at the centennial celebration of the promulgation of Avogadro's Hypothesis, for the best work in molecular physics which should appear in the three following years, i. e., during 1912, 1913, and 1914, has been awarded to my report to the Carnegie Institution on investigations in osmotic pressure.

"I hasten to inform you, because I am glad to have justified the confidence you have shown in the work and the liberal support you have given it, without which it would have been impossible for me to have succeeded."

Succession in the Presidency.

The stately march and the inevitable sequences of time are shown also in the current history of the Institution by provision for retirement, at the end of this calendar year, at his request made in December 1918, of the present incumbent in the Presidency, and by the election to this position, on May 25, 1920, of Dr. John C. Merriam, for many years professor of paleontology and historical geology and dean of the faculties in the University of California. Thus it happens that within the first two decades after the foundation of the Institution it will have had three administrative heads. The terms of office of the first two Presidents are 3 and 16 years, respectively; but while these are rather brief in the average as regards the needs of so novel an establishment, they are much above the average tenure of similar positions in the nearest comparable organizations, namely, colleges and universities. It should be recalled, however, that the first President of the Institution was past seventy years of age when he assumed the arduous duties of this office, and that his successor was past fifty-five years of age when he undertook to assist in forwarding and in stabilizing the swiftly expanding developments which followed; so that neither had time to make a career in this field, and the best that either could hope to realize was a favorable start and a conservative growth for the new organization.

As related in preceding reports, the Institution, like most other contemporary establishments, has been profoundly affected by the consequences of the world war, although these have come on so gradually and with such diversified ramifications that only those giving constant attention to them may be expected to be aware of their present and ultimate effects. Nevertheless, one salient fact, namely, the diminishing value of incomes, suffices to account for the principal difficulties which have overtaken the Institution. It should be evident, indeed, that no altruistic organization can go on expanding indefinitely when the purchasing capacity of its income has fallen to one-half its initial value. As a matter of fact, if the Institution did not have a reserve fund, it would be obliged to restrict its work to something like two-thirds to one-half the present program. As the case stands, it is only truth to state that much of this work has been curtailed, much has been postponed, while some projects have been abandoned so far as a speedy realization is concerned.

Post-war Conditions.

In the meantime, conditions in the departments of research and with the investigatory staffs generally have undergone some degree of improvement. Most of the investigators who were drawn off during the war into government service or into the activities of industrial life have returned to their posts, in some cases to accept salaries much less than those offered by industrial concerns. But while the initial and the major derangements due to the world war are subsiding, there remain more persistent, though minor, sources of disquiet which must decrease efficiency in research for a decade or more in the immediate future. These sources are found mainly in the unprecedented costs of living, in the general scarcity of housing accommodations, and in the prevalent depression of all kinds of securities in which earnings and savings have been invested. The immanence of these untoward circumstances is little conducive to the serenity commonly held essential in the higher types of contemplative work. It should be observed, however, in this connection, that many, if not most, of the discoveries and advances of our race have been made under the spur of dire necessity, and there is much reason to hope that the hyper-anæmic and neurasthenic state in which

humanity now finds itself is only a symptomatic prelude to an era of greater enlightenment and of progressive development.

Recrudescence of Fallacies.

Probably no other organization in the evolution of learning has been so beset by what Dr. Johnson called the anfractuosities of the human mind as the Carnegie Institution of Washington. Much in its history would be incredible if it had not occurred, and much is so far stranger than fiction that few would believe it without the evidence which comes from personal contact. Many of our contemporaries, indeed, find it easier, if not more rational, to dispute the evidence than to grapple with its crudities and subtleties. It should be observed, however, that while the vagaries to which reference is made here have been greatly stimulated by the mere existence of the Institution, these did not originate with it or at the time of its foundation in 1902. They are, on the contrary, as old as primitive man. The excess of their revival now is only a manifestation of the atavistic tendencies against which progress must long, if not always, contend, and especially during periods of national and international turmoil.

Adequate discussion of this complex subject must be left to the historian and to the psychologist who may work in calmer times than ours. Many of the data they will need are indicated in previous reports, while the archives of the Institution contain a vast store of materials for those who may have the fortitude to undertake the tasks of an analysis and melioration of these adventitious stumbling-blocks which impede rational development in the Institution and in all similar organizations as well. But while this is neither an appropriate time nor an appropriate place for anything like a comprehensive exposition of the Institution's unrivaled experience in the elusive domain of futility, it appears essential to reiterate protest against certain of the more obstinate and prevalent misconceptions concerning the plainest matters of fact, misconceptions inimical alike to the interests of the Institution and to its contemporaries.

When the Institution was founded, now nearly two decades ago, it was in the nature of things that the wildest flights of poetic idealism should be tolerated or even welcomed, in accord with

the popular theory that it is worth while to winnow a great bulk of chaff if only a few grains of wheat can be found. Thus it happened that a vast aggregate of unrealizable expectations was generated and a correspondingly vast aggregate of disappointment necessitated, not because of any personalities involved, but because of the relentless operation of the rules of arithmetic and the laws of probability. After this early period of phantasms was passed, and after the Institution secured a charter defining its functions, it became the duty of the Trustees, subject to the inexorable limitations imposed by those rules and laws, to justify the existence of the Institution by concentrating attention upon practicable researches and conducting them persistently to logical conclusions. But while this policy led speedily to tangible results, and is the only efficient policy, it did not remove the early common, and probably still prevalent, impressions that the Institution could finance worthy projects without limit, that it is under no moral obligations to live within income, and that it may proceed regardless of legal restrictions and of the maxims dictated by the age-long experience of our race. It should go without saying that the Institution has attempted none of these follies; it is almost inconceivable, in fact, that any responsible body of men would now entertain such illusions, although history records numerous instances of similar obliquities on the part of fiduciary agents. Nevertheless, it must be admitted that no organization has arrived at a stage of stability and permanence until it has won public confidence in its integrity and in its freedom from suspicions of "frenzied finance." If the Institution is to live and to prosper it must evolve steadily away from the fantastic ideas of those who speak and write without reflection and as steadily toward the rational penetration of those who speak and write only after deliberate contemplation.

Citation of two concrete cases of current fallacies may suffice to show how inimical, in some respects, are the conditions under which the Institution exists; and it may be observed that any similarly endowed establishment must encounter similarly untoward conditions.

(1) Belief in the unlimited capacities of a limited income and disbelief in the capacities of the Institution itself to apply that

income advantageously have been all along so common that their revival in these harder times should not be altogether surprising. It is little short of amazing, however, to find that many eminent minds outside the Central Empires see no reasons why the Institution may not meet, in the role of research, the needs and deficiencies of other organizations, whose incomes, and presumably, therefore, resources, are in some cases two to four times those of the Institution. Much has been said in previous reports in contradiction of the opinion that the Institution has difficulty in finding capable men and worthy objects for the application of funds in the fields of research. This opinion is little flattering to thinking men, whether within or without the Institution, since it has no foundation in fact. What was said about this matter after seven years of observation and reflection, in the report for 1912, has been steadily emphasized by subsequent experience, to wit:

"That there are the amplest room and the amplest opportunity for research establishments without danger of encroachment on establishments founded for other purposes; that it is not difficult for the Institution to find appropriate ways in which to apply its income; that there are, in fact, in plain sight ten times as many worthy, practicable subjects of research and ten times as many worthy investigators as the income of the Institution can advantageously subsidize."

(2) The other current fallacy referred to arises from the facts that the Institution has a reserve fund, a pension fund, and an insurance fund. Those who take no thought of the morrow do not hesitate to increase the evils of the present by mistaking caution for timidity and by mistaking forethought for incompetency. Thus it happens that many of our contemporaries think that the existence of these funds is prima-facie evidence of incapacity to make good use of them. Some legislators go so far even as to look upon reserve funds as serving only to rob the present in order to enrich the future, and hence it seems logical to them to tax such accumulations out of existence. Here, again, as in most considerations vital to the Institution, a knowledge of reality is essential to correct the misapprehensions in question; but it is not evident that much progress has been made in the acquirement and in the dissemination of such knowledge since the foundation of the Institution in 1902.

Some Publications of the Year.

Although greatly increased costs of printing, illustrations, etc., for current publications and corresponding increases in costs of works long in press have prevented authorization of the usual number of new publications, the number of books issued during the year falls not far short of the yearly average for the past decade. Of this list three may be cited here by reason of their diversity in subject-matter and by reason of special contemporary interests they have aroused.

Attention was invited in the report of a year ago to the publication of Volume I of Professor Dickson's History of the Theory of Numbers. Volume II (octavo, pp. xxv+803) of this work has appeared during this year. It is devoted to what is now called "Diophantine Analysis," cultivated alike by the ancient, the medieval, and the modern schools of mathematicians. It is remarkable as the branch of mathematics which has the greatest number of devotees; and its history shows well how the higher developments in science are evolved, in general, out of amateurism and dilettantism. Hence the desirability of commending both these latter stages while at the same time urging individuals to linger in neither. It is especially noteworthy in the volume in question that the French statesman Fermat (1601–1665) should be one of the most prominent of the many famous names which adorn this sort of analysis. It has turned out, in fact, that he is more distinguished for his "Opera Mathematica" than for his high conduct as councillor for the parliament of Toulouse.

Soon after the establishment of the Department of Embryology (December 1914) under the directorship of Professor Franklin P. Mall, his associates planned to celebrate the completion of his approaching quarter-century of work at the Johns Hopkins University by the dedication to him of a volume of contributions in his favorite fields of research. His untimely death, however, November 17, 1917, prevented realization of this spontaneous tribute from his colleagues and left them the unexpected but not less spontaneous obligation of supplying a memorial volume. This has been prepared under the auspices

of the Department of Embryology and issued during the year as publication No. 272 of the Institution's series (quarto, pp. v+554, with a portrait of Mall). It contains twenty distinct papers from as many different authors, whose common aim has been to furnish at once a fitting testimonial to their inspiring leader and an exemplification of the high standards he attained in all his work.

Early in the history of the Institution a multitude of proposals more or less, but mostly less, definite for work in the inclusive domain of anthropology were entertained. Indeed, the number, the importance, and the great prospective costs of such proposals were soon seen, by those obliged to consider the limitations involved, to be hopelessly beyond the capacities of the Institution's income. But quite apart from this insuperable obstacle in the way of speedy and effective entrance into that domain, there were, and are, two other obstacles hardly less insurmountable. These are, first, a lack of a consensus of opinion as to the content of anthropology, and, secondly, a prevalent inability to relieve ourselves of prepossessions in approaching this science. Herein is found an explanation of the fact that the highly objective physical sciences have advanced much more rapidly and securely than the highly subjective humanistic sciences, as well as an explanation of the fact that it was ten times as easy, say, to establish the Mount Wilson Observatory as it would be to set up a department devoted to anthropology in the comprehensive sense of the term. Thus far it must be said that even in America, where so much has been done during the past half-century to give definiteness to the word, anthropology is commonly confounded with one of its subdivisions, namely, archeology; while the latter in turn, until recently, has been usually restricted to the antiquities of the peoples who have dwelt about the shores of the Mediterranean Sea.

Nevertheless, in spite of the obstacles referred to, and in spite of the great excess in this, as in other domains, of opportunities over capacities of available means, much work has been accomplished by the Institution in the large group of apparently diverse though intrinsically related fields now designated as component parts of anthropology. Nearly a hundred volumes

of works, with an aggregate of more than 30,000 pages, have previously appeared, and to these has been added during the year an important contribution by Sylvanus G. Morley, Associate in Central American Archeology, entitled "The Inscriptions at Copan" (quarto, pp. xii+643). This gives the results of researches extending over nearly a decade, but much interrupted by the world war and by the difficulties of exploration in the forests of a tropical climate. All those interested in the pursuit of the numerous investigations which in our day, or in the near future, promise to penetrate the mythology which has hitherto veiled the origin and the progress of primitive man, will join in the hope that this volume by Morley may be only the first of a series of contributions from his pen toward an understanding of Mayan civilization.

RESEARCHES OF THE YEAR.

Although, for the reasons alluded to in the preceding section, it will probably be years before the Institution can realize in its affairs anything like a near return to pre-war conditions, tendencies toward such a return are manifested alike in the activities of the departments of research and in those of the individual Associates. Departmental staffs, so much disorganized and deflected during the war, have undergone substantial reconstruction, while Associates and their collaborators, who were similarly disorganized, are likewise returning to their suspended work. Except for the elements of cost, it would be easy in most respects to return to the pre-war status, since competent investigators, along with the rest of the world, appreciate the fact that the need for and the stimulus to research have never been so great as at present. But how this element of increased expense is to be met is a question asked by all members of the Institution and remains as yet unanswered.

In the meantime, the productivities of the Institution and its capacities therefor are increasing. What has been accomplished up to date should be regarded as an earnest of what can be done rather than as a manifestation of normal efficiency. In many, if not most, of the fields of research under cultivation progress is necessarily of a secular character; individuals may come and go, but the phenomena to be investigated abide or proceed indefinitely with ever increasing entanglements as knowledge enlarges. In general, therefore, it appears irrelevant to inquire when the work of a department of research, or of the Institution as a whole, will be finished. In the nature of things this is a question which we must refer to our successors, who may be expected to be better qualified than we to give an appropriate answer, even if they observe with us that "the stars are still shining young and clear as when the shepherds first noted them on the plains of Shinar."

By reason of the secular nature of the work of the Institution just referred to, and by reason of the impetus acquired before the war, the intellectual output, as measured by contributions to journals and to the proceedings of learned societies and as measured by investigations in progress, has not been seriously

diminished during the past six years. And it is gratifying to note that during the past year, especially, the return towards normal activities has been accompanied as a rule by greater concentration of effort and by prospects of more important results than have characterized any previous year in the history of the Institution. Accumulated experience, of course, has afforded its advantages here; but the researches of the year, as recorded in the formal accounts printed in the current Year Book and as indicated in the bibliography accompanying this report, show that only the restricted capacities of the Institution's resources stand in the way of its increased opportunities and its increased usefulness.

FINANCIAL RECORDS.

Financial Statement for Fiscal Year 1919–1920.

The sources of funds available for expenditure during the past fiscal year, the allotments for the year, the revertments made during the year, and the balances unalloted at the end of the year, are shown in detail in the following statement:

Financial statement for fiscal year 1919–1920.

Object of appropriation.	Balances unallotted Oct. 31, 1919.	Appropriation Dec. 12, 1919.	Revertments Nov. 1, 1919, to Oct. 31, 1920.	Totals for fiscal year.	Aggregates of allotments and amounts transferred.	Balances unallotted Oct. 31, 1920.
Large grants...	....	$897,316	$30,118.34	$927,434.34	$927,434.34	....
Minor grants...	$4,400.10	118,900	49,321.51	172,621.61	161,200.66	$11,520.95
Publications....	9,200.12	60,000	4,879.57	74,079.69	68,930.69	5,149.00
Administration.	....	55,000	9,795.00	64,795.00	64,795.00	....
Reserve fund...	....	250,000	....	250,000.00	250,000.00	....
Insurance fund.	....	25,000	....	25,000.00	25,000.00	....
Pension fund...	....	40,000	....	40,000.00	40,000.00	....
Total.........	13,600.22	1,446,216	94,114.42	1,553,930.64	1,537,360.69	16,669.95

The aggregates of receipts from interest on endowment, from interest on bond investments, from interest on deposits in banks,

Receipts and Expenditures of the Institution to Date.

from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by the following table; the grand total of these to date is $18,972,089.26.

Aggregates of financial receipts.

Year ending Oct. 31	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications.	Refund on grants.	Miscellaneous items.	Total.
1902	$250,000.00	$9.70	....	....	$1,825.52	$251,835.22
1903	500,000.00	5,867.10	$2,286.16	....	101.57	508,254.83
1904	500,000.00	33,004.26	2,436.07	$999.03	....	536,439.36
1905	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,100,000.00	31,118,41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,100,375.00	67,888.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917	1,100,408.75	100,702.60	11,921.35	32,950.22	179,611.97	1,425,594.89
1918	1,110,427.45	120,464.02	9,921.00	39,833.23	255,354.60	1,536,000.30
1919	1,112,441.25	138,700.73	12,837.58	53,549.98	214,498.99	1,532,028.53
1920	1,112,441.25	159,559.03	18,393.79	4,088.63	176,249.81	1,470,732.51
Total	15,419,907.87	979,901.51	169,581.91	167,138.26	2,235,559.71*	18,972,089.26

* Of this amount $1,394,335 came from the sale of bonds in 1908, 1909, 1910, 1912, 1913, 1914, 1915, 1916, 1917, 1918; $51,265.74 from the Colburn Estate in 1916; and $750,000 from the Carnegie Corporation of New York in 1917, 1918, 1919, and 1920.

The following list shows the departments and divisions for which appropriations have been made by the Trustees and the amounts allotted by the Executive Committee during 1920:

Department of Botanical Research	$64,723.26
Ecological Research	24,840.00
Department of Embryology	43,128.00
Eugenics Record Office	30,785.76
Department of Experimental Evolution	78,343.27
Geophysical Laboratory	125,852.00
Department of Historical Research	40,696.58
Department of Marine Biology	27,628.88
Department of Meridian Astrometry	38,912.00
Nutrition Laboratory	52,432.39
Division of Publications	15,000.00
Mount Wilson Observatory	181,665.68
Department of Terrestrial Magnetism	203,426.52
Aggregate for Minor Grants	117,050.00
Aggregate for Publications	68,930.69
Total	1,113,415.03

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be summarily classified under five heads: (1) Investments in bonds; (2) large projects; (3) minor and special projects; (4) publications; (5) administration.

The following table shows the actual expenditures under these heads for each year since the foundation of the Institution:

Purposes for which funds have been appropriated.

Year ending Oct. 31.	Investments in bonds.	Large projects.	Minor and special projects.	Publications.	Administration.	Total.
1902	....	....	$4,500.00	....	$27,513.00	$32,013.00
1903	$100,475.00	....	137,564.17	$938.53	43,627.66	282,605.36
1904	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	427,941.40	83,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	454,609.75	72,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914	861,864.23	817,894.52	107,507.55	44,670.55	44,159.54	1,876,096.39
1915	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917	502,254.05	695,813.07	100,746.13	62,884.61	48,766.29	1,410,464.15
1918	528,565.55	693,780.00	170,470.74	44,394.83	49,118.76	1,486,329.88
1919	438,960.29	845,123.82	203,810.84	68,964.23	55,742.83	1,612,602.01
1920	464,279.57	876,437.28	159,633.49	95,933.10	68,739.90	1,665,023.34
Total	5,286,897.94	9,584,116.95	2,144,717.25	853,309.78	868,527.85	18,737,569.80

Investments in Property. On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended since the foundation of the Institution:

Schedule of real estate, equipments, and publications.

Administration:		
Building, site, and equipment		$337,904.36
Department of Botanical Research (Sept. 30, 1920):		
Buildings and grounds	$36,071.08	
Laboratory and library	20,702.82	
Operating appliances	18,636.51	
		75,410.41
Eugenics Record Office (Sept. 30, 1920):		
Library, furniture, and operating appliances	11,905.52	
Archives	45,274.49	
Buildings and land	130,526.13	
		187,706.14
Department of Experimental Evolution (Sept. 30, 1920):		
Buildings, office, library, and grounds	128,095.58	
Laboratory apparatus	11,882.20	
Field	21,222.21	
		161,199.99

*Real estate and equipment, original cost.

Schedule of real estate, equipments, and publications—continued.

Geophysical Laboratory (Sept. 30, 1920):		
Building, library, operating appliances	$170,855.98	
Laboratory apparatus	77,224.72	
Shop equipment	10,933.36	
		$259,014.06
Department of Historical Research (Sept. 30, 1920):		
Office	2,622.97	
Library	4,083.55	
		6,706.52
Department of Marine Biology (Sept. 30, 1920):		
Vessels	31,180.43	
Buildings, docks, furniture, and library	12,120.36	
Apparatus and instruments	8,745.30	
		52,046.09
Department of Meridian Astrometry (Sept. 30, 1920):		
Apparatus and instruments	2,453.41	
Operating	3,332.70	
		5,786.11
Nutrition Laboratory (Sept. 30, 1920):		
Building, office, and shop	121,303.23	
Laboratory apparatus	25,021.29	
		146,324.52
Mount Wilson Observatory (Aug. 31, 1920):		
Buildings, grounds, road, and telephone line	191,298.30	
Shop equipment	38,649.55	
Instruments	448,374.08	
Furniture and operating appliances	136,390.00	
Hooker 100-inch reflector	561,477.79	
		1,376,189.72
Department of Terrestrial Magnetism (Sept. 30, 1920):		
Building, site, and office	163,197.19	
Vessel and survey equipment	149,024.00	
Instruments, laboratory, and shop equipment	87,052.00	
		399,273.19
Publications:		
Stock on hand at sale price (Oct. 31, 1920)	309,654.35	
Outstanding accounts (Oct. 31, 1920)	3,335.38	
		312,989.73
		3,320,550.84

Expenses of Maintenance of Administration Building.

The cost of maintenance of the Administration Building, including the items of fuel, lighting, janitorial services, maintenance of grounds, repairs, and other incidental expenses, has been, for 1910, $2,981.65; for 1911, $2,641.53; for 1912, $2,919.89; for 1913, $2,601.15; for 1914, $3,251.08; for 1915, $3,955.60; for 1916, $2,870.51; for 1917, $3,272.50; for 1918, $3,891.80; for 1919, $3,834.38; for 1920, $6,339.17. Of this latter amount $2,295.00 was for reconstruction of roof.

PUBLICATIONS.

Publications Authorized and Issued during the Year.

The publication of 8 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of $29,350.00. The following list gives the titles and names of authors of the publications issued during the year; it includes 22 volumes, with an aggregate of 3,840 octavo pages and 3,710 quarto pages. Sixteen additional volumes are now in press.

List of publications issued during the year.

Year Book, No. 18, 1919. Octavo, XVI+380 pages, 2 plates, 4 figs.
Index Medicus, Second Series, Vol. 17, 1919. Octavo, 1,167 pages.
Seventh and Eighth Editions of an Illustrated Pamphlet on the Scope and Organization of the Carnegie Institution of Washington. Octavo, 55 pages, 42 plates.
No. 53. Muller, W. Max. Egyptological Researches. Vol. 3, The Bilingual Decrees of Philæ. Quarto, 88 pages, 41 plates.
No. 85. Hasse, Adelaide R. Index of Economic Material in the Documents of the States of the United States. Quarto. Pennsylvania (1790-1904). Part I, A to E, pp. 1–810.
No. 161. Moulton, F. R., in collaboration with Daniel Buchanan, Thomas Buck, Frank L. Griffin, William R. Longley, and William D. MacMillan. Periodic Orbits. Quarto, XIV+524 pages, 50 figures.
No. 185. Hasse, Adelaide R. Index to United States Documents relating to Foreign Affairs, 1828–1861. In 3 parts. Quarto. Part II, I to Q, pages 795–1331.
No. 219. Morley, Sylvanus G. The Inscriptions at Copan. Quarto, XIV+644 pages, 34 plates, 93 figures.
No. 248. Britton, N. L., and J. N. Rose. The Cactaceae. Descriptions and Illustrations of Plants of the Cactus Family. Quarto, in 4 volumes. Vol. 2, VII+239 pages, 40 plates, 305 figures.
No. 256. Dickson, L. E. History of the Theory of Numbers. Octavo. Vol. 2, Diophantine Analysis. XXV+803 pages, 12 figures.
No. 272. Contributions to Embryology. Nos. 27 to 46. Vol. IX. Quarto, 561 pages, 64 plates, 78 text figures., 14 charts.

This book contains the following papers:

Macklin, Charles C. The Development and Function of Macrophages in the Repair of Experimental Bone-wounds in Rats vitally stained with Trypan-blue. (Contribution No. 27.) 46 pages, 4 plates.
Duesberg, J. Cytoplasmic Structures in the Seminal Epithelium of the Opossum. (Contribution No. 28.) 38 pages, 2 plates, 5 text figures.
Corner, George W. On the Widespread Occurrence of the Reticular Fibrils produced by Capillary Endothelium. (Contribution No. 29.) 9 pages, 2 plates.
Wheeler, Theodora. Variability in the Spinal Column as regards Defective Neural Arches (Rudimentary Spina Bifida). (Contribution No. 30.) 13 pages, 11 figures.
Van der Stricht, O. The Arrangement and Structure of Sustentacular Cells and Hair Cells in the Developing Organ of Corti. (Contribution No. 31.) 34 pages, 4 plates.
Retzer, Robert. The Sino-ventricular Bundle: A Functional Interpretation of Morphological Findings. (Contribution No. 32.) 14 pages, 1 plate.
Jenkins, George B. A Study of the Superior Olive. (Contribution No. 33.) 16 pages, 2 plates, 1 text figure.
Schultz, Adolph H. The Development of the External Nose in Whites and Negroes. (Contribution No. 34.) 18 pages, 1 plate, 7 figures.
Lewis, Margaret Reed. Muscular Contraction in Tissue Cultures. (Contribution No. 35.) 22 pages, 2 plates, 6 text figures.
Sabin, Florence R. Studies on the Origin of Blood-vessels and of Red Blood-corpuscles as seen in the Living Blastoderm of Chicks during the Second Day of Incubation. (Contribution No. 36.) 50 pages, 6 plates, 1 text figure.
Bean, Robert B. Notes on the Post-natal Growth of the Heart, Kidneys, Liver, and Spleen in Man. (Contribution No. 37.) 22 pages, 8 text figures.

List of publications issued during the year—continued.

No. 272—continued.

Miller, William S. A Morphological Study of the Tracheal and Bronchial Cartilages. (Contribution No. 38.) 14 pages, 2 plates, 11 text figures.

Lewis, Warren H. The Cartilaginous Skull of a Human Embryo 21 millimeters in length. (Contribution No. 39.) 26 pages, 5 plates.

Meyer, Arthur W. Hydatiform Degeneration in Tubal and Uterine Pregnancy. (Contribution No. 40.) 40 pages, 6 plates.

Meyers, Burton D. A Study of the Development of Certain Features of the Cerebellum. (Contribution No. 41.) 11 pages, 6 figures.

Essick, Charles R. Formation of Macrophages by the Cells lining the Subarachnoid Cavity in response to the Stimulus of Particulate Matter. (Contribution No. 42.) 12 pages, 1 plate.

Streeter, George L. A Human Embryo (Mateer) of the Presomite Period. (Contribution No. 43.) 36 pages, 7 plates, 4 text figures, 3 charts.

Weed, Lewis H. The Experimental Production of an Internal Hydrocephalus. (Contribution No. 44.) 22 pages, 2 plates.

Clark, Eliot R., and Eleanor Linton Clark. On the Origin and Early Development of the Lymphatic System of the Chick. (Contribution No. 45.) 36 pages, 7 plates, 15 text figures.

Bardeen, C. R. The Height-weight Index of Build in relation to Linear and Volumetric Proportions and Surface Area of the Body during Post-natal Development. (Contribution No. 46.) 72 pages, 11 charts, 2 text figures.

No. 274. Contributions to Embryology, Nos. 49 to 55. Vol. XI. Quarto, III+170 pages, 15 plates, 12 text figures, 6 charts.

This book contains the following papers:

Danchakoff, Vera. Myeloid Metaplasia of the Embryonic Mesenchyme in relation to Cell Potentialities and Differential Factors. (Contribution No. 49.) 32 pp., 5 plates.

Lineback, Paul E. Studies on the Longitudinal Muscle of the Human Colon, with special reference to the Development of the Tæniæ. (Contribution No. 50.) 12 pp., 8 figures.

Wislocki, George B. Experimental Studies on Fetal Absorption. I, The Vitally Stained Fetus. II, The Behavior of the Fetal Membranes and Placenta of the Cat toward Colloidal Dyes injected into the Maternal Blood-stream. (Contribution No. 51.) 16 pp., 4 plates, 1 text figure.

Ingalls, N. William. A Human Embryo at the Beginning of Segmentation, with special reference to the Vascular System. (Contribution No. 52.) 30 pp., 5 plates, 1 text figure.

Barry, Lee Willis. The Effects of Inanition in the Pregnant Albino Rat, with Special Reference to the Changes in the Relative Weights of the Various Parts, Systems, and Organs of the Offspring. (Contribution No. 53.) 46 pp.

Corner, George W. A Case of True Lateral Hermaphroditism in a Pig with Functional Ovary. (Contribution No. 54.) 6 pp., 1 plate.

Streeter, George L. Weight, Sitting Height, Head Size, Foot Length, and Menstrual Age of the Human Embryo. (Contribution No. 55.) 28 pp., 2 figures, 6 charts.

No. 281. Papers from the Department of Marine Biology of the Carnegie Institution of Washington. Vol. XIII. Octavo, IV+128 pages, 19 plates, 3 figures.

This book contains the following papers:

Speidel, Carl Caskey. Gland Cells of Internal Secretion in the Spinal Cord of the Skates. 31 pages, 9 plates, 3 figures.

Drew, Gilman A. The Structure and Ejaculation of the Spermatophores of *Octopus americana*. 14 pages, 3 plates.

Clark, Hubert Lyman. The Distribution of the Littoral Echinoderms of the West Indies. 25 pages., 3 plates.

Harvey, E. Newton. Further Studies on the Chemistry of Light Production in Luminous Organisms. 35 pages.

Gudger, E. W. The Ovary of *Felichthys felis*, the Gaff-topsail Catfish: Its Structure and Function. 17 pages, 4 plates, 1 figure.

No. 282. Bartsch, Paul. Experiments in the Breeding of Cerions. Paper from the Department of Marine Biology of the Carnegie Institution of Washington. Vol. XIV. Octavo, 56 pages, 59 plates.

No. 289. Douglass, A. E. Climatic Cycles and Tree-Growth: A study of the Annual Rings of Trees in relation to Climate and Solar Activity. Octavo, 127 pages, 12 plates, 40 figures.

List of publications issued during the year—continued.

No. 290. Clements, Frederic E. Plant Indicators: The Relation of Plant Communities to Processes and Practice. Octavo, xvi+388 pages, 92 plates, 25 figures.

No. 292. Weaver, John E. Root Development in the Grassland Formation: A correlation of the Root Systems of Native Vegetation and Crop Plants. Octavo, 151 pages, 2 maps, 23 plates, 39 figures.

No. 294. Mortensen, Th. Studies in the Development of Crinoids. Paper from the Department of Marine Biology of the Carnegie Institution of Washington. Vol. XVI. Quarto, iv+94 pages, 28 plates, 10 figures.

No. 296. Key, Wilhelmine E. Heredity and Social Fitness: Study of Differential Mating in a Pennsylvania Family. (Paper No. 32, Station for Experimental Evolution of the Carnegie Institution of Washington.) Octavo, 102 pages, 2 charts, 2 figures.

No. 297. MacDougal, Daniel T. Hydration and Growth. Octavo, vi+176 pages, 52 figures.

No. 298. Nichols, Edward L., and H. L. Howes, in collaboration with Ernest Merritt, D. T. Wilber, and Frances G. Wick. Fluorescence of the Uranyl Salts. Octavo, 241 pages, 1 plate, 11 figures.

Sales of Publications and Value of those on hand. The following table shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution:

Table showing sales of publications.

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903.....	$2,256.91	$29.25	....
1904.....	2,370.47	52.85	$12.75
1905.....	2,562.76	44.75	431.44
1906.....	2,970.56	37.60	1,341.52
1907.....	3,676.71	56.50	2,292.89
1908.....	3,406.19	99.65	4,371.67
1909.....	4,821.85	73.01	6,287.21
1910.....	4,470.50	100.70	5,899.05
1911.....	4,440.21	85.50	6,366.55
1912.....	4,652.14	61.65	6,782.34
1913.....	4,992.02	75.95	7,140.69
1914.....	5,079.16	49.65	6,273.59
1915.....	5,010.21	47.60	5,239.98
1916.....	4,382.19	46.60	8,115.37
1917.....	4,616.21	51.55	7,253.59
1918.....	4,324.29	21.10	5,575.61
1919.....	4,267.95	93.30	8,476.33
1920.....	5,451.86	40.50	12,901.43
Total...	73,752.19	1,067.71	94,762.01

At the end of the fiscal year there are on hand 98,412 volumes of miscellaneous publications and Year Books, having a sale value of $288,930.85; also 37,593 numbers of the Index Medicus, having a sale value of $20,723.50. The total sale value of publications on hand is therefore $309,654.35. It is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent also by sales, a total of 209,316 volumes of publications of the Institution.

Growth and Extent of Institution's Publications.

The data furnished in the following table are of statistical interest in respect to the work of publication of the Institution. Four hundred and twenty-four volumes, embracing a total of 118,695 pages of printed matter, have thus far been issued by the Institution.

Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the nineteen years from 1902 to 1920.

Year.	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages.
1902......	3	46	......	46
1903......	3	1,667	......	1,667
1904......	11	2,843	34	2,877
1905......	21	3,783	1,445	5,228
1906......	19	3,166	1,288	4,454
1907......	38	6,284	3,428	9,712
1908......	28	4,843	2,485	7,328
1909......	19	3,695	1,212	4,907
1910......	29	3,274	4,831	8,105
1911......	30	5,062	1,670	6,732
1912......	23	3,981	2,044	6,025
1913......	29	6,605	2,752	9,357
1914......	23	4,978	1,934	6,912
1915......	23	4,686	1,466	6,152
1916......	35	9,478	2,430	11,908
1917......	21	4,464	2,691	7,155
1918......	17	3,073	1,269	4,193
1919......	29	5,834	2,431	8,265
1920......	23	3,962	3,710	7,672
Total...	424	81,724	37,120	118,695

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK OF INVESTIGATORS, ASSOCIATES, AND COLLABORATORS.

Under this heading it is sought to include titles of all publications proceeding from work done under the auspices of the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (pp. 21–23).

Abetti, Giorgio. See Joy, Alfred H.

Adams, L. H., and E. D. Williamson. A note on the annealing of optical glass. (Papers on Optical Glass, No. 30.) Jour. Opt. Soc. Amer., vol. 4, 213–223 (1920).

———. See Williamson, E. D.

Adams, Walter S., and Cora G. Burwell. The spectrum of Nova Ophiuchi, 1919. Astrophys. Jour., vol. 51, 121–126 (1920); Mt. Wilson Contr., No. 179.

———, and Alfred H. Joy. Nova Ophiuchi. Pubs. A. S. P., vol. 31, 307–308 (1919).

———, ———. The spectra of two Algol variables of long period. Pubs. A. S. P., vol. 31, 308 (1919).

———, ———. The spectrum of Nova Lyræ 1919. Pubs. A. S. P., vol. 32, 154–155 (1920).

———, ———. The spectrum of the companion to Castor and W. B. 16^{h}906. Pubs. A. S. P., vol. 32, 158–160 (1920).

———, ———. Changes in the spectrum of Omicron Ceti. Pubs. A. S. P., vol. 32, 163–165 (1920).

———, ———. Helium lines in novæ spectra. Observatory, vol. 43, 86–87 (1920).

———, ———, and Gustaf Strömberg. Radial velocities and parallaxes of additional stars in the Taurus group. Read at Seattle meeting, A. S. P. (1920); (Abstract) Pubs. A. S. P., vol. 32, 194–195 (1920).

———, ———, ———. The spectra of some companions to stars of the B-type. Read at the Seattle meeting, A. S. P. (1920) (Abstract) Pubs. A. S. P., vol. 32, 195 (1920).

———, ———, ———. Summary of spectroscopic parallax determinations. Read at Seattle meeting, A. S. P. (1920); (Abstract) Pubs. A. S. P., vol. 32, 195–196 (1920).

Albrecht, Sebastian. On progressive changes of the wave-lengths of lines in stellar spectra with change of type. Astrophys. Jour., vol. 50, 277.

Anderson, John A. The spectrum of electrically exploded wires. Astrophys. Jour., vol. 51, 37–48 (1920); Mt. Wilson Contr., No. 178.

———. Application of Michelson's interferometer method to the measurement of close double stars. Astrophys, Jour., vol. 51, 263–275 (1920); Mt. Wilson Contr., No. 185.

———. Spectra of explosions. Proc. Nat. Acad. Sci., vol. 6, 42–43 (1920); Mt. Wilson Communications, No. 65.

———. The Michelson interferometer method for measuring close double stars. Pubs. A. S. P., vol. 32, 58–59 (1920).

———. The sun as a source of energy. Jour. Electricity, vol. 44, 201–302 (1920).

Ault, J. P. Preliminary results of ocean magnetic observations on the *Carnegie* from Washington to Dakar and Buenos Aires, October 1919 to January 1920. Terr. Mag., vol. 25, No. 1, 9–13 (Mar. 1920).

———. Preliminary results of ocean magnetic observations on the *Carnegie* from Buenos Aires, South America, to St. Helena, February and March 1920. Terr. Mag., vol. 25, No. 2, 49–52 (June 1920).

———. Preliminary results of ocean magnetic observations on the *Carnegie* from St. Helena to Cape Town, thence to Colombo, Ceylon, April to June 1920. Terr. Mag., vol. 25, No. 3, 117–122 (Sept. 1920).

Ayer, J. B. See Weed, L. H.

Babcock, Harold D. Note on the polarization of the north sky. Astrophys. Jour., vol. 50, 228–231 (1919); Mt. Wilson Contr., No. 171.

———. See St. John, Charles E.

Banta, A. M., and Mary Gover. An analysis of the sexual modifications of an appendage in sex-intergrade *Daphnia longispina*. Anat. Rec., vol. 17, 348–349 (Jan. 1920).

Barnett, S. J. Note on electromagnetic induction and relative motion. (Abstract) Phys. Rev., ser. 2, vol. 15, No. 6, 527–528 (June 1920).

———. A double solenoid for the production of uniform magnetic fields. Phil. Mag., vol. 40, No. 238, 519–520 (Oct. 1920).

Barus, Carl. Example of torsional viscous retrogression. Proc. Nat. Acad. Sci., vol. 5, 1–3 (1919).

———. Elongation due to magnetization. Proc. Nat. Acad. Sci., vol. 5, 267–272 (1919).

———. The interference of rapid vibrations chiefly in relation to telephone currents. Proc. Nat. Acad. Sci., vol. 5, 331–340 (1919).

———. Pressure variation of the specific heat of liquids. Proc. Nat. Acad. Sci., vol. 5, 340–344 (1919).

Barus, Carl. Displacement of gravitating needles, etc. Proc. Nat. Acad. Sci., vol. 5, 547–550 (1919).

———. The motion of a gravitating needle. Science, n. s., vol. 50, 214–216 (1919).

———. The interaction of gravitating and radiant forces. Science, n. s., vol. 50, 279–282 (1919).

———. On spiral nebulæ. Science, n. s., vol. 52, 112–113 (1920).

Bauer, L. A. Additional note on the International Geodetic and Geophysical Union. U. S. Dept. Agric., Monthly Weath. Rev., vol. 47, No. 11, 806 (Nov. 1919).

———. The total solar eclipse of May 29, 1919, at Cape Palmas, Liberia. (Abstract) U. S. Dept. Agric., Monthly Weath. Rev., vol. 47, No. 11, 808–809 (Nov. 1919).

———. Résumé of observations concerning the solar eclipse of May 29, 1919, and the Einstein effect. Science, n. s., vol. 51, No. 1317, 301–311 (Mar. 26, 1920).

———. Preliminary results of analysis of light deflections observed during the solar eclipse of May 29, 1919. Science, n. s., vol. 51, No. 1328, 581–583 (June 11, 1920).

———. Further results of analysis of light deflections observed during the solar eclipse of May 29, 1919. Science, n. s., vol. 52, No. 1337, 147 (Aug. 13, 1920).

———. Procedure at the magnetic observatories of the Carnegie Institution of Washington. Terr. Mag., vol. 24, No. 4, 149–153 (Dec. 1919).

———. The cruises of the *Carnegie*. World's Work, vol. 39, No. 3, 280–301 (Jan. 1920).

———. Results and analysis of magnetic observations during the solar eclipse of May 29, 1919—Summary I. Terr. Mag., vol. 25, No. 3, 81–98 (Sept. 1920).

Beattie, James A. The activity coefficient of normal potassium chloride solution and the potential of the normal calomel electrode. Jour. Amer. Chem. Soc., vol. 42, 1128–1131 (1920).

———. See MacInnes, Duncan A.

Behre, Ellinor H., and Oscar Riddle. The effect of quinine on the nitrogen content of the egg albumen of ring doves. Amer. Jour. Phys., vol. 50, No. 3, 364–376 (1919).

Benedict, Francis G. The basal metabolism of boys from 1 to 13 years of age. Proc. Nat. Acad. Sci., 6, 7 (1920).

———. Notes on the use of the portable respiration apparatus. Boston Med. and Surg. Jour., 182, 243 (1920).

———, W. E. Collins, Mary F. Hendry, and Alice Johnson. A respiration chamber for large domestic animals. Tech. Bull. 16, N. H. Coll. Agric. (1920).

v. Bichowsky, F. Russell. A practical test of the resistance of optical glass to weathering. (Papers on Optical Glass, No. 23*a*.) Jour. Amer. Ceram. Soc., vol. 3, 296–304 (1920).

———. Note on the mechanics of the weathering of glass. (Papers on Optical Glass, No. 23*b*.) Jour. Amer. Ceram. Soc., vol. 3, 309–312 (1920).

Bjerknes, V. The structure of the atmosphere when rain is falling. Quart. Jour. Royal Meteor. Soc., vol. 46, No. 194, 119–140 (Apr. 1920).

———. Meteorology of the temperate zone and the general atmospheric circulation. Nature, 522 (June 24, 1920).

———. Sur le temperature des hautes couches atmosphériques. Compte rendu de l'acad. des Sci., Paris, t. 170, 604, 747 (Mar. 8 and Mar. 22, 1920).

Blakeslee, A. F. Sexuality in mucors. Science, n. s., vol. 51, 375–382 (Apr. 16, 1920) and 403–409 (Apr. 23, 1920). Address of vice-president and chairman of Section G, Botany, A. A. A. S., St. Louis (Dec. 30, 1919).

Boss, Benjamin. On the real motions of the stars (Paper 2). Astron. Jour., No. 771 (June 1920).

Bowen, N. L. Optical properties of anthophyllite. Jour. Wash. Acad. Sci., vol. 10, 411–414 (1920).

Bridges, C. B. White ocelli: An example of a "slight" mutant character with normal variability. Biol. Bul., vol. 38, 231–236 (Apr. 1920).

———. See Morgan, T. H.; Sturtevant, A. H.

Buddington, A. F. See Ferguson, J. B.

Burwell, Cora G. See Adams, Walter S.

Cannon, W. A. The ecological relations of roots. Science, n. s., vol. 51, 393–394 (1920).

Carver, E. K. See Richards, T. W.

Case, E. C. On a very perfect thoracic shield of a large labyrinthodont in the geological collections of the University of Michigan. Occasional papers, Mus. Zool., Univ. Mich., No. 82, 3, 1 pl. (Apr. 28, 1920).

———. Preliminary description of a new suborder of phytosaurian reptiles, with a description of a new species of *Phytosaurus*. Jour. Geol., vol. 23, No. 6 (1920).

Cash, James R. On the development of the lymphatics in the stomach of the embryo pig. Anat. Rec., vol. 16, 145 (1919).

Castle, W. E. Does evolution occur exclusively by loss of genetic factors? Amer. Nat., vol. 53, 555–558 (Nov. 1919).

———. Are genes linear or non-linear in arrangement? Proc. Nat. Acad. Sci., vol. 5, 500–506 (Nov. 1919).

CASTLE, W. E. The measurement of linkage. Amer. Nat., vol. 54, 264–267 (May 1920).
———. Linked genes in rabbits. Science, n. s., vol. 52, 156, 157 (Aug. 13, 1920).
CHOW, MING. Free energy of potassium hydroxide in aqueous solution and the activities of its ions. Jour. Amer. Chem. Soc., vol. 42, 488–497 (Mar. 1920).
———. Activities of the ions in solutions of mixed electrolytes. Jour. Amer. Chem. Soc., vol. 42, 497–502 (Mar. 1920).
COBLE, ARTHUR B. The ten nodes of the rational sextic and the Cayley symmetroid. Amer. Jour. Math., vol. 41, No. 4, 243–265 (Oct. 1919).
COLLINS, W. E. See BENEDICT, FRANCIS G.
CORNER, GEORGE W. On abnormalities of the pig embryo occurring before attachment to the uterus. Anat. Rec., vol. 18, 229 (1920).
CUNNINGHAM, R. S. The reaction of peritoneal mesothelium to granular suspensions and laked blood. Anat. Rec., vol. 18, 229 (1920).
CUSHMAN, J. A. Observations on living specimens of *Iridio diaphana*, a species of Foraminifera. Proc. U. S. Nat. Mus., vol. 57, 153–158, pls. 19–21 (1920).
DANIELS, F. See RICHARDS, T. W.
DAVENPORT, C. B. A strain producing multiple births. Jour. Hered., vol. 10, 382–384 (Nov. 1919).
———. Influence of the male in the production of twins. (Reprint.) Med. Rec., vol. 97, 509–511. (Mar. 27, 1920).
———. Influence of the male in the production of human twins. Amer. Nat., vol. 54, 122–129 (Mar. 1920).
———. Heredity of twin births. Proc. Soc. Exper. Biol. and Med., vol. 17, 75–77 (1920).
———. See LOVE, A. G.; RITZMAN, E. G.
DAVIS, CARL L. The relation of the somites of the head to the brain in a human embryo of twenty paired somites. Anat. Rec., vol. 18, 232 (1920).
DAVIS, HELEN N. See SHAPLEY, HARLOW.
DAY, ARTHUR L. Optical glass and its future as an American industry. (Papers on Optical Glass, No. 26.) Jour. Franklin Inst., vol. 190, 453–472 (1920).
———. Memorial of George Ferdinand Becker. Bull. Geol. Soc. Amer., vol. 31, 14–25 (1920).
DICKINSON, ROSCOE G. Crystal structures of wulfenite and scheelite. Jour. Amer. Chem. Soc., vol. 42, 85–93 (Jan. 1920).
DUGGAR, B. M. The micro-colorimeter in the indicator method of hydrogen determination. Ann. Mo. Bot. Gard., vol. 6, 179 (1919).
———. Some factors in research. Plant World, vol. 22, 277 (1919).
———. Hydrogen-ion concentration and the composition of nutrient solutions in relation to the growth of seed plants. Ann. Mo. Bot. Gard., vol. 7, 1 (1920).
DUNCAN, JOHN C. Bright nebulæ and star clusters in Sagittarius and Scutum photographed with the 60-inch reflector. Astrophys. Jour., vol. 51, 4–12 (1920); Mt. Wilson Contr. No. 177.
———. See SHAPLEY, HARLOW.
FELTON, L. D. See WEED, L. H.
FENNER, CLARENCE N. The Katmai region, Alaska, and the great eruption of 1912. Jour. Geol., vol. 28, 569–606 (1920).
FERGUSON, J. B. The term "inversion." Science, n. s., vol. 50, 544–546 (1919).
———, and A. F. BUDDINGTON. The binary system åkermanite gehlenite. Amer. Jour. Sci., vol. 50, 131–140 (1920).
FERRY, EDNA L. Nutrition experiments with rats: A description of methods and technic. Jour. Lab. and Clin. Med., vol. 5, 735–745 (1920).
———. See OSBORNE, THOMAS B.
FIRKET, J. On the origin of germ cells in higher vertebrates. Anat. Rec., vol. 18, 309–316 (1920).
FLEMING, J. A. Description of glass magnetogram scale used by the Department of Terrestrial Magnetism. Terr. Mag., vol. 24, No. 4, 154–155 (Dec. 1919).
———, and W. F. WALLIS. The construction and equipment of the Watheroo Magnetic Observatory. Terr. Mag., vol. 25, No. 1, 1–6, 1 pl. (Mar. 1920).
FREED, E. STANLEY. See NOYES, A. A.
FUSEYA, G. Solubility of mercuric oxide in sodium hydroxide solutions. Jour. Amer. Chem. Soc., vol. 42, 368–371 (Mar. 1920).
GARARD, I. D. See SHERMAN, H. C.
GREENBERG, J. P. An unusual case of tuberculous salpingitis. Johns Hopkins Hosp. Bull., vol. 31, 132–133 (1920).
GOVER, MARY. See BANTA, A. M.
HALE, GEORGE E. Preliminary results of a comparative test of the 60-inch and 100-inch telescopes of the Mount Wilson Observatory. Pubs. A. S. P., vol. 31, 257–260 (1920).
———. Lunar photography with the Hooker telescope. Pubs. A. S. P., vol. 32, 112–115 (1920).
———. Photographs taken with the 100-inch reflector of the Mount Wilson Observatory. Monthly Notices, vol. 80, 240–243 (1920).

HALL, N. F. See RICHARDS, T. W.

HARRIS, J. ARTHUR. Charles Buckman Goring. Science, n. s., vol. 51, 183–184 (Feb. 1920).

———. Food requirements and food expenditures of men and women. Quart. Pub. Amer. Stat. Ass., vol. 17, 133–134 (Mar. 1920).

———. Practical universality of field heterogeneity as a factor influencing plot yields. Jour. Agric. Res., 19, 279–314 (July 1920).

HARVEY, E. NEWTON. The nature of animal light. ix+182 pp., 33 figs. (1920).

HAY, OLIVER P. Descriptions of some Pleistocene vertebrates found in the United States. Proc. U. S. Nat. Mus., vol. 58, 83–146 (1920).

HENDRY, MARY F. See BENEDICT, FRANCIS G.

HEUSER, CHESTER H. The digestion tract of the opossum at birth. Anat. Rec., vol. 18, 234 (1920).

HOGUE, MARY J. The effect of hypotonic and hypertonic solutions on fibroblasts of the embryonic chick heart *in vitro*. Jour. Exp. Med., vol. 30, 617–648 (1919).

HOSTETTER, J. C. See ROBERTS, H. S.

HUBBLE, EDWIN P. The spectrum of N. G. C. 1499. Pubs. A. S. P., vol. 32, 155–156 (1920).

———. The planetary nebulæ I. C. 2003. Pubs. A. S. P., vol. 32, 161 (1920).

———. Twelve new variable stars. Pubs. A. S. P., vol. 32, 161–162 (1920).

———. See SEARES, FREDERICK H.

HUMASON, MILTON. A seventeenth nova in the Andromeda nebula. Pubs. A. S. P., vol. 32, 63 (1920).

———. See NICHOLSON, SETH B.

JEANS, J. H. See STRÖMBERG, GUSTAF.

JOHNSON, ALICE. See BENEDICT, FRANCIS G.

JONES, E. E. See LITTLE, C. C.

JOY, ALFRED H., and GIORGIO ABETTI. The orbit of the spectroscopic binary Boss 2285. Astrophys. Jour., vol. 50, 391–393 (1919); Mt. Wilson Contr., No. 172.

———. See ADAMS, WALTER S.

KAPTEYN, J. C., and P. J. VAN RHIJN. On the distribution of the stars in space, especially in the high galactic latitudes. Astrophys. Jour., vol. 52, 23–38 (1920); Mt. Wilson Contr., No. 188.

KIDSON, E. Magnetic storm of December 15, 1919, as recorded at the Watheroo Magnetic Observatory. Terr. Mag., vol. 25, No. 1, 14–15 (Mar. 1920).

———. Magnetic disturbances, earthquake records, and aurora at Watheroo Magnetic Observatory, March 1920. Terr. Mag., vol. 25, No. 2, 61–62 (June 1920).

———. Earthquakes recorded at Watheroo Observatory, May 1920. Terr. Mag., vol. 25, No. 3, 142 (Sept. 1920).

KING, ARTHUR S. The characteristics of absorption spectra produced by the electric furnace. Astrophys. Jour., vol. 51, 13–22 (1920); Mt. Wilson Contr., No. 174.

———. Preliminary observations of the Zeeman effect for electric furnace spectra. Astrophys. Jour., vol. 51, 107–120 (1920); Mt. Wilson Contr., No. 180.

———. Observations of the electric furnace spectra of cobalt, nickel, barium, strontium, and calcium in the region of greater wave-length. Astrophys. Jour., vol. 51, 179–186 (1920); Mt. Wilson Contr., No. 181.

———. A study of absorption spectra with the electric furnace. Proc. Nat. Acad. Sci., vol. 6, 63–65 (1920); Mt. Wilson Communications, No. 66.

———. A study of the effect of a magnetic field on electric furnace spectra. Proc. Nat. Acad. Sci., vol. 6, 65–66 (1920); Mt. Wilson Communications, No. 67.

———. The Zeeman effect for electric furnace spectra. Read at the St. Louis meeting, Amer. Phys. Soc. (1920); (Abstract) Phys. Rev. Ser. 2, vol. 15, 237–238 (1920).

KOCH, MATHILDE L., and OSCAR RIDDLE. Further studies on the chemical composition of the brain of normal and ataxic pigeons. Jour. Comp. Neurol., vol. 31, No. 2, 83–110 (1919).

LA MER, V. K. See SHERMAN, H. C.

LAUGHLIN, H. H. Illustrating the structure and mathematics of the human germ-plasm. Jour. Hered., vol. 11, No. 4, 185–189 (Apr. 1920).

———. Calculating ancestral influence in man. Proc. Nat. Acad. Sci., vol. 6, No. 5, 235–242 (May 1920).

LEWIS, M. R. The rapid formation of vacuoles due to the presence of Bacillus typhosus in the cells of tissue cultures. Anat. Rec., vol. 18, 239 (1920).

———. The formation of vacuoles due to Bacillus typhosus in the cells of tissue cultures of the intestine of the chick embryo. Jour. Exp. Med., vol. 31, 293–311 (1920).

LEWIS, W. H. The behavior of the centriole and the centrosphere in degenerating fibroblasts of tissue cultures. Amer. Jour. Phys., vol. 49 (1919).

———. Giant centrospheres in degenerating mesenchyme cells of tissue cultures. Jour. Exp. Med., vol. 31, 275–292 (1919).

———. The action of potassium permanganate on the mesenchyme cells in tissue cultures. Anat. Rec., vol. 18, 240 (1920).

LINEBACK, P. E. Studies on the longitudinal muscle of the human colon, with special reference to the tæniæ. Anat. Rec., vol. 16, 155 (1919).

LITTLE, C. C. Color inheritance in cats, with special reference to the colors, black, yellow, and tortoise-shell. Jour. Genetics, vol. 8, 279–280 (1919).

———. A note on the origin of piebald spotting in dogs. Jour. Hered., vol. 11, No. 1, 12–15 (Jan. 1920).

———. Alternative explanations for exceptional color classes in doves and canaries. Amer. Nat., vol. 54, 152–175 (1920).

———. The heredity and susceptibility to a transplantable sarcoma (J. w. B.) of the Japanese waltzing mouse. Science, n. s., vol. 51, 467–468 (1920).

———. Is there linkage between the genes for yellow and for black in mice? Amer. Nat., vol. 54, 267–270 (1920).

———. A note on the human sex-ratio. Proc. Nat. Acad. Sci., vol. 6, 250–253 (1920).

———, and E. E. JONES. The inheritance of coat color in Great Danes. Jour. Hered., vol. 10, 309–320 (1920).

LOVE, A. G., and C. B. DAVENPORT. Defects found in drafted men: Statistical information compiled from the draft records under the direction of the Surgeon General, M. W. Ireland. Printed for the use of the Senate Committee on Military Affairs, 66th Cong., 1st Sess., Wash., Govt. Print. Office, 359 pages (1919).

LOWE, E. A. The Bobbio Missal, a Gallican mass-book (MS. Paris Lat. 13246) (1920).

———. The unique manuscript of Apuleius' Metamorphoses (Flor. Laur. 68.2) and its oldest transcript (Flor. Laur. 29.2). Class. Quart., vol. 14, pp. 150 *et seq.* (1920).

LYNCH, RUTH S. The growth of embryonic chick liver in tissue cultures. Anat. Rec., vol. 18, 249 (1920).

MACDOUGAL, D. T. Hydration and growth. Proc. Amer. Phil. Soc., vol. 58, 346–372 (1919).

———. The physical factors in the growth of the tomato. Bull. Torrey Bot. Club, vol. 47, 261 (1920).

———. Auxographic measurement of swelling of biocolloids and of plants. Bot. Gaz., vol. 70, 126–136 (1920).

———. Swelling of agar in solutions of amino acids and related componds. Bot. Gaz., vol. 70, 268–278 (1920).

———, and H. A. SPOEHR. Hydration effects of amino-compounds. Proc. Soc. Exp. Biol. and Med., vol. 17, 33–36 (1919).

———, ———. The components and colloidal behavior of plant protoplasm. Proc. Amer. Phil. Soc., vol. 19, No. 1, 150 (1920).

MACDOWELL, E. C. Bristle inheritance in *Drosophila*. III: Correlation. Jour. Exp. Zool.. vol. 30, 419–460, 8 figs.

MACINNES, DUNCAN A., and JAMES A. BEATTIE. The free energy of dilution and the transference numbers of lithium chloride solution. Jour. Amer. Chem. Soc., vol. 42, 1117–1128 (June 1920).

———. See NOYES, A. A.

MACKLIN, C. C., and M. T. MACKLIN. Brain repair in the rat vitally stained with trypan blue. Anat. Rec., vol. 16, 156 (1919).

———, ———. A study of brain repair in the rat by the use of trypan blue. Arch. Neurol. and Phys., vol 3, 353–394 (1920).

MATSUMOTO, T. The granules, vacuoles, and mitochondria in the sympathetic nerve fibers cultivated *in vitro*. Johns Hopkins Hosp. Bull., vol. 31, 91–93 (1920).

MAUCHLY, S. J. Comments on Dechevrens' electric tide observations. Terr. Mag., vol. 24, No. 4, 179 (Dec. 1919).

———, and A. THOMSON. Results of atmospheric-electric observations made at Sobral, Brazil, during the total solar eclipse of May 29, 1919. Terr. Mag., vol. 25, No. 2, 41–48 (June 1920); (Abstract) Phys. Rev., ser. 2, vol. 15, No. 6, 525–526 (June 1920).

MAYOR, A. G. The effect of diminished oxygen upon the note of nerve-conduction in *Cassiopea*. Amer. Jour. Physiol., vol. 51, 543–549 (Apr. 1920).

———. The reefs of Tutuila, Samoa, in their relation to coral-reef theories. Proc. Amer. Philos. Soc., vol. 19, No. 3, 14 pp., 3 figs. (1920).

MCKIBBEN, P. S. See WEED, L. H.

MEISENHELTER, N. A cruise on the brigantine *Carnegie*. Nat. Marine, vol. 15, No. 6, 10–18 (June 1920).

MENDEL, LAFAYETTE B. The fat-soluble vitamine. N. Y. State Jour. Med. (July 1920).

MERRILL, PAUL W. Note on the air lines in spark spectra from λ5927 to λ8719. Astrophys. Jour., vol. 51, 236–243 (1920); Mt. Wilson Contr., No. 183.

———. A variable star with a peculiar spectrum. Pubs. A. S. P., vol. 31, 305–307 (1919).

———. Progress in photography resulting from the war. Pubs. A. S. P., vol. 32, 16–26 (1920).

———. Miscellaneous items relating to the spectra of long-period variable stars. Read at Seattle meeting, A. S. P. (1920); (Abstract) Pubs. A. S. P., vol. 32, 196 (1920).

———. The spectrum of R Aquarii at minimum brightness. Pubs. A. S. P., vol. 32, 247–248 (1920).

———. The chemistry of the stars. Address at joint meeting of Phi Beta Kappa and Sigma Xi, Seattle (1920); at Berkeley meeting, A. S. P. (1920).

Merwin, H. E. Chemical researches on sediments. Bull. Geol. Soc. Amer., vol. 31, 300–309 (1920).
Metz, Charles W. The arrangement of genes in *Drosophila virilis*. Proc. Nat. Acad. Sci., vol. 6, No. 4, 164–166 (Apr. 1920).
———. Correspondence between chromosome number and linkage groups in *Drosophila virilis*. Science, n. s., vol. 51, No. 1321, 417–418 (Apr. 1920).
———. Observations on the sterility of mutant hybrids in *Drosophila virilis*. Proc. Nat. Acad. Sci., vol. 6, No. 7, 421–423 (July 1920).
Michelson, A. A. On the application of interference methods to astronomical measurements. Astrophys. Jour., vol. 51, 257–262 (1920); Mt. Wilson Contr., No. 184.
Miles, Walter R. A pursuit pendulum. Psych. Rev., vol. 27, 361 (1920).
Morey, George W. Classification and nomenclature of optical glass. (Papers on Optical Glass, No. 28.) Jour. Opt. Soc. Amer., vol 4, 205–212 (1920).
———. American optical glass for American instruments. Am. Photography, vol. 14, 129–133 (1919).
Morgan, T. H. Effects of castration of hen-feathered Campines. Biol. Bull., vol. 39 (1920).
———. Variations in the secondary sexual characters of the fiddler crab. Amer. Nat. vol. 54, 220–246 (May-June 1920).
———, A. H. Sturtevant, and C. B. Bridges. Evidence for the linear order of the genes. Proc. Nat. Acad. Sci., vol. 6, 152–164 (Apr. 1920).
———. See Wilson, E. R.
Neun, D. E. See Sherman, H. C.
Nicholson, Seth B. Two sun-spots close to the sun's equator. Pubs. A. S. P., vol. 31, 277–278 (1919).
———. The satellites in the solar system. Pubs. A. S. P., vol. 32, 139–144 (1920).
———. The magnetic polarity of the sun-spot group of March 21, 1920. Pubs. A. S. P., vol. 32, 244–246 (1920).
———, and Milton Humason. Metcalf's first comet. Pubs. A. S. P., vol. 31, 280 (1919).
———. See St. John, Charles; Shapley, Harlow.
Nolan, Owen L. See Osborne, Thomas B.
Noyes, A. A., and E. Stanley Freed. A thermodynamic investigation of reactions involving silver sulfide and silver iodide. Jour. Amer. Chem. Soc., vol. 43, 476–487 (Mar. 1920).
———, and Duncan McInnes. The ionization and activity of largely ionized substances. Jour. Amer. Chem. Soc., vol. 42, 239–245 (Feb. 1920).
Osborne, Thomas B. The story of the vitamines: A thorough discussion of the vital principles of food: Parts I, II, III, IV, and V. Rural New Yorker (Aug. 23, 1919; Aug. 30, 1919; Sept. 6, 1919; Sept. 13, 1919; Sept. 20, 1919).
———. The water-soluble vitamine. N. Y. State Jour. Med. (July 1920).
———, and Lafayette B. Mendel. Nutritive factors in plant tissues. II: The distribution of water-soluble vitamine. Jour. Biol. Chem. (Aug. 1919).
———, ———. Do fruits contain water-soluble vitamine? Proc. Soc. Exper. Biol. and Med. (Nov. 1919).
———, ———. Fat-soluble vitamine of green foods. Proc. Amer. Soc. Biol. Chem.; Jour. Biol. Chem (Mar. 1920).
———, ———. Nutritive factors in plant itssues. III: Further observations on the distribution of water-soluble vitamine. Jour. Biol. Chem. (Mar. 1920).
———, ———. Nutritive factors in plant tissues. IV: Fat-soluble vitamine. Jour. Biol. Chem. (Apr. 1920).
———, ———. Nutritive value of the proteins of the barley, oat, rye, and wheat kernels. Jour. Biol. Chem. (Mar. 1920).
———, ———. Milk as a source of water-soluble vitamine. II. Jour. Biol. Chem. (Apr. 1920).
———, ———. Occurrence of water-soluble vitamine in some common fruits. Jour. Biol. Chem. (July 1920).
———, and Owen L. Nolan. Does gliadin contain amide nitrogen? Jour. Biol. Chem. (Sept. 1920).
———, and Alfred J. Wakeman. Extraction and concentration of the water-soluble vitamine from brewer's yeast. Jour. Biol. Chem. (Dec. 1919).
———, ———. Proteins of green leaves. I. Spinach leaves. Jour. Biol. Chem. (May 1920.)
———, ———, and Edna L. Ferry. Preparation of protein free from water-soluble vitamine. Jour. Biol. Chem. (Aug. 1919).
Pease, Francis G. Photographs of nebulæ with the 60-inch reflector, 1917–1919. Astrophys. Jour., vol. 51, 276–308 (1920); Mt. Wilson Contr., No. 186.
———. The ring nebula B. D. +30°3639. Pubs. A. S. P., vol. 31, 276–277 (1919).
Prigosen, Rosa E. Vacuoles formed in certain cells studied under abnormal conditions. Anat. Rec., vol. 18, 254 (1920).

RICHARDS, T. W., E. K. CARVER, and W. C. SCHUMB. Effect of pressure and dissolved air and water on the melting-point of benzene. Jour. Amer. Chem. Soc., vol. 41, 2019 (Dec. 1919).
———, and F. DANIELS. Concentrated thallium amalgams: Their electrochemical and thermochemical behavior, densities, and freezing-points. Jour. Amer. Chem. Soc., vol. 41, 1732 (Nov. 1919).
———, and N. F. HALL. Melting-points and thermoelectric behavior of lead isotopes. Jour. Amer. Chem. Soc., vol. 42 (Aug. 1920).
———, and J. SAMESHIMA. Compressibility of indium. Jour. Amer. Chem. Soc., vol. 42, 49 (Jan. 1920).
———, and J. W. SHIPLEY. Dielectric constants of typical aliphatic and aromatic hydrocarbons, cyclohexane, cyclohexanone, and cyclohexanol. Jour. Amer. Chem. Soc., vol. 41, 2002 (Dec. 1919).
———, and S. TAMARU. A calorimetric method for standardizing thermometers by electrical energy. Jour. Amer. Chem. Soc., vol. 42 (July 1920).
RIDDLE, OSCAR. See BEHRE, ELLINOR H.; KOCH, MATHILDE L.
RITCHIE, MARY. Observations of Barnard's variable near Messier 11. Pubs. A. S. P., vol. 32, 61–62 (1920).
RITZMAN, E. G., and C. B. DAVENPORT. A comparison of some traits of conformation of Southdown and Rambouillet sheep and of their F_1 hybrids, with preliminary data and remarks on variability in F_2. Tech. Bull. No. 15, N. H. College Agric. Exper. Sta., 32 pp., pl. VII (Apr. 1920).
ROBERTS, H. S., and J. C. HOSTETTER. The manufacture and uses of rolled optical glass. (Papers on Optical Glass, No. 24.) Jour. Amer. Ceram. Soc., vol. 3, 750–761 (1920).
SAMESHIMA, J. See RICHARDS, T. W.
SANFORD, ROSCOE F. The spectrum of T Tauri. Pubs. A. S. P., vol. 32, 59–61 (1920).
———. Three spectroscopic binary stars. Read at Seattle meeting, A. S. P. (1920); Pubs. A. S. P., vol. 32, 192–194 (1920).
SARTON, GEORGE. Avant Propos [du tome II]. Isis, vol. 2, 313–314 (1919).
———. War and civilization. Isis, vol. 2, 315–321 (1919).
———. La synthese geologique de 1775 à 1918. Isis, vol. 2, 357–394, 2 pls. (1919).
———. VI[e] Bibliographie critique de toutes les publications relatives à l'histoire, la philosophie et l'organisation de la science (jusqu' en aôut 1914). Isis, vol. 2, 429–480 (1919).
———. Secret history. Scribner's Mag., vol. 67, 187–192 (Feb. 1920).
———. Herbert Spencer. Scribner's Mag., vol. 67, 695–702 (June 1920).
———. The faith of a humanist. Isis, vol. 3, 3–6 (1920).
———. Seventh critical bibliography of the history of philosophy and organization of science and of the history of civilization (to June 1919). Isis, vol. 3, 90–154 (1920).
——— (editor). Isis: International review devoted to the history of science and civilization. Vol. 2, 313–488 (1919); vol. 3, 1–156 (1920).
SCHULTZ, A. H. An apparatus for measuring the newborn. Johns Hopkins Hosp. Bull., vol. 31, 131–132 (1920).
SCHUMB, W. C. See RICHARDS, T. W.
SEARES, FREDERICK H. The surface brightness of the galactic system as seen from a distant external point and a comparison with spiral nebulæ. Astrophys. Jour., vol. 52, 162–182 (1920); Mt. Wilson Contr., No. 191.
———. Magnitudes of faint comparison stars for Nova Persei, No. 2. Astrophys. Jour., vol. 52, 183–186 (1920); Mt. Wilson Contr., No. 192.
———. The general magnetic field of the sun. Observatory, vol. 43, 310–322 (1920).
———, and EDWIN P. HUBBLE. The color of the nebulous stars. Astrophys. Jour., vol. 52, 8–22 (1920); Mt. Wilson Contr., No. 187.
SHAPLEY, HARLOW. Studies based on the colors and magnitudes in stellar clusters. Fifteenth paper: A photometric analysis of the globular system Messier 68. Astrophys. Jour., vol. 51, 49–61 (1920); Mt. Wilson Contr., No. 175.
———. Studies based on the colors and magnitudes in stellar clusters. Seventeenth paper: Miscellaneous results. Astrophys. Jour., vol. 52, 73–85 (1920); Mt. Wilson Contr., No. 190.
———. Studies of magnitudes in star clusters. X: Spectral type B and the local stellar system. Proc. Nat. Acad. Sci., vol. 5, 434–440 (1919); Mt. Wilson Communications, No. 64.
———. Studies of magnitudes in star clusters. XI: Frequency curves of the absolute magnitude and color index for 1,152 giant stars. Proc. Nat. Acad. Sci., vol. 6, 293–300 (1920): Mt. Wilson Communications, No. 69.
———. Note on a simple device for increasing the photographic power of large telescopes. Proc. Nat. Acad. Sci., vol. 6, 127–130 (1920); Mt. Wilson Communications, No. 68.
———. Thermokinetics of *Liometopum apiculatum* Mayr. Proc. Nat. Acad. Sci., vol. 6, 204–211 (1920).
———. On the existence of external galaxies. Pubs. A. S. P., vol. 31, 261–268 (1919).
———. Note on a sensitive spectrographic arrangement. Pubs. A. S. P., vol. 31, 278–280 (1919).

SHAPLEY, HARLOW. W Virginis. Pubs. A. S. P., vol. 32, 156–158 (1920).
———. Photometric parallaxes of nine Cepheid variables. Pubs. A. S. P., vol. 32, 162–163 (1920).
———. Star clusters and the structure of the universe. Scientia, vol. 26, 269–276, 353–361 (1919); vol. 27, 93–101, 185–193 (1920).
———. Notes on the Formicidæ of Mount Wilson. Bull. Ecol. Soc. Amer., vol. 3, 229 (1919).
———. Note on pterergates in the Californian harvester ant. Psyche, vol. 27, 72–74 (Aug. 1920).
———, and HELEN DAVIS. Studies based on the colors and magnitudes in stellar clusters. Sixteenth paper: Photometric catalogue of 848 stars in Messier 3. Astrophys. Jour., vol. 51, 140–178 (1920); Mt. Wilson Contr., No. 176.
———, and JOHN C. DUNCAN. Novæ in the Andromeda nebula. Pubs. A. S. P., vol. 31, 280–281 (1919).
———, and SETH B. NICHOLSON. On the spectral lines of a pulsating star. Proc. Nat. Acad. Sci., vol. 5, 417–423 (1919); Mt. Wilson Communications, No. 63.
SHEPHERD, E. S. Two gas collections from Mauna Loa. Bull. Hawaiian Volcano Observ.. vol. 8, 65–67 (1920).
SHERMAN, H. C. Protein requirement of maintenance in man. Proc. Nat. Acad. Sci., vol. 6, 38–40 (Jan. 1920).
———, I. D. GARARD, and V. K. LA MER. A further study of the process of purifying pancreatic amylase. Jour. Amer. Chem. Soc., vol. 42, 1900–1907 (Sept. 1920).
———, and D. E. NEUN. Proteolytic activity of pancreatic amylase preparations. Jour. Amer. Chem. Soc., vol. 41, 1855–1862 (Nov. 1919).
———, and F. WALKER. Influence of aspartic acid and asparagin upon the enzymic hydrolysis of starch. Jour. Amer. Chem. Soc., vol. 41, 1866–1873 (Nov. 1919).
SHIPLEY, J. W. See RICHARDS, T. W.
SHIPLEY, P. G. The physiological significance of the reaction of tissue cells to vital benzidene dyes. Amer. Jour. Phys., vol. 49, 284–301 (1919).
SHREVE, FORREST. A comparison of the vegetational features of two desert mountain ranges. Plant World, vol. 22, 291–307 (1919).
SMITH, D. T. Melanin pigment in the pigmented epithelium of the retina of the embryo chick's eye, studied *in vivo* and *in vitro*. Anat. Rec., vol. 18, 260 (1920).
SPAULDING, M. H. The early recognition of sex from the external genitalia in human embryos 15 to 50 mm. long. Anat. Rec., vol. 18, 261 (1920).
SPOEHR, H. A. See MACDOUGAL, D. T.
ST. JOHN, CHARLES E. The astronomical bearing of the theory of generalized relativity. Seattle meeting, A. S. P. (1920); (Abstract) Pubs. A. S. P., vol. 32, 191 (1920).
———. The spectroscopic committee of the Division of Physical Sciences of the Research Council. Read at Seattle meeting, A. S. P. (1920); (Abstract) Pubs. A. S. P., vol. 32, 192 (1920).
———. Displacement of solar lines and the Einstein effect. Observatory, vol. 43, 158–162 (1920).
———. The displacement of solar spectral lines. Observatory, vol. 43, 260–262 (1920).
———, and HAROLD D. BABCOCK. Concerning tables of solar wave-lengths in the International system. Read at Seattle meeting, A. S. P., (1920); (Abstract) Pubs. A. S. P., vol. 32, 192 (1920).
———, and SETH B. NICHOLSON. Relative wave-lengths of sky-light and Venus-reflected sunlight. Read at Seattle meeting, A. S. P. (1920); (Abstract) Pubs. A. S. P., vol. 32, 194 (1920).
STREETER, G. L. Formation of single ovum twins. Johns Hopkins Hosp. Bull., vol. 30, 235–238 (1919).
———. Embryological significance of the crus helicis. Anat. Rec, vol. 18, 263 (1920).
STRÖMBERG, GUSTAF. Note on the relationship of mean parallax to mean proper motion. Mt. Wilson Contr., No. 170.
———, and J. H. JEANS. Problems of cosmogony and stellar dynamics. Cambridge (1919) (a review); Pubs. A. S. P., vol. 32, 50–53 (1920).
———. Note on the use of the geometrical mean parallax. Pubs. A. S. P., vol. 32, 244 (1920).
———. See ADAMS, WALTER S.
STURTEVANT, A. H. The vermilion gene and gynandromorphism. Proc. Soc. Exper. Biol. and Med., vol. 17, 70–71 (1920).
———. Intersexes in *Drosophila simulans*. Science, n. s., vol. 51, 325–327 (Mar. 26, 1920).
———. The dipterous genus *Zygothrica*. Proc. U. S. Nat. Mus. (1920).
———. See MORGAN, T. H.
Summary of Mount Wilson magnetic observations of sun-spots for May and June 1920. Pubs. A. S. P., vol. 32, 236–240 (1920).
SWANN, W. F. G. Atmospheric electricity. Jour. Franklin Inst., vol. 188, No. 5, 577–606 (Nov. 1919).
TALBOT, FRITZ B. The caloric requirements of normal infants and children from birth to puberty. Jour. Diseases of Children, 18, 229 (1919).

TAMARU, S. See RICHARDS, T. W.
THOMSON, A. See MAUCHLY, S. J.
VAN MAANEN, ADRIAAN. The photographic determination of stellar parallaxes with the 60-inch reflector: fourth series. Mt. Wilson Contr., No. 182.
———. Note on the parallax of Cepheid variables. Pubs. A. S. P., vol. 32, 62 (1920).
———. The parallax of Nova Aquilæ No. 3. Pubs. A. S. P., vol. 32, 62–63 (1920).
———. The parallaxes of N. G. C. 40 and N. G. C. 2022. Pubs. A. S. P., vol. 32, 158 (1920).
———. Parallax notes. Pubs. A. S. P., vol. 32, 241–242 (1920); Read at Seattle meeting, A. S. P. (1920).
———, and CORAL WOLFE. On the systematic differences in trigonometrically determined parallaxes. Mt. Wilson Contr., No. 189.
VAN RHIJN, P. J. On the brightness of the sky at night and the total amount of star-light. Astrophys. Jour., vol. 50, 356–375 (1919); Mt. Wilson Contr., No. 173.
———. See KAPTEYN, J. C.
WAKEMAN, ALFRED J. See OSBORNE, THOMAS B.
WALKER, F. See SHERMAN, H. C.
WALLIS, W. F. Earthquake of April 30, 1919, as recorded on the magnetogram at Watheroo Observatory. Terr. Mag., vol. 24, No. 4, 174 (Dec. 1919).
———. See FLEMING, J. A.
WASHINGTON, H. S. Italite: A new leucite rock. Jour. Wash. Acad. Sci., vol. 10, 270–272 (1920); Amer. Jour. Sci., vol. 50, 33–47 (1920).
———. The rhyolites of Lipari. Amer. Jour. Sci., vol. 50, 446–462 (1920).
———. Sull' italite: un nuovo tipo di roccia leucitica. Atti dell' Accad. dei Lincei, vol. 29, 424–435 (1920).
WEED, L. H. Changes in the cells of the arachnoidea. Anat. Rec., vol. 18, 265 (1920).
———, and P. S. MCKIBBEN. The effect of intravenous injections of various concentrations upon the central nervous system. Anat. Rec., vol. 16, 167 (1919).
———, ———. Pressure changes in the cerebrospinal fluid following intravenous injection of solutions of various concentrations. Amer. Jour. Phys., vol. 48, 512–530 (1919).
———, ———. Experimental alteration of the brain bulk. Amer. Jour. Phys., vol. 48, 531–558 (1920).
———, and P. WEGEFARTH. Experimental irrigation of the subarachnoid space. Jour. Phar. and Exper. Therap., vol. 13, 317–334 (1919).
———, ———, J. B. AYER, and L. D. FELTON. The influence of certain experimental procedures upon the production of meningitis by intravenous inoculation. A study of experimental meningitis. Monograph Rockefeller Inst., 57–111 (1920).
———, ———, ———, ———. The production of meningitis by release of cerebrospinal fluid during experimental septicemia. Jour. Amer. Med. Assn., vol. 72, 190–193 (1919).
WEGEFARTH, P. See WEED, L. H.
WESCOTT, ERNEST W. The equilibrium between chlorine and plumbous and plumbic chlorides in aqueous solution. Jour. Amer. Chem. Soc., vol. 42, 1335–1349 (July 1920).
WHITE, W. P. Estimating impurities by means of the melting-point curve. Jour. Phys. Chem., vol. 24, 393–416 (1920).
———. Methods of increasing the precision of thermostats. Jour. Wash. Acad. Sci., vol. 10, 429–432 (1920).
WIELAND, G. R. Distribution and relationships of the Cycadeoids (an address). Amer. Jour. Bot., 154-171, pl. VII (Apr. 1920).
———. The Tetracenutron-Drimys question. Amer. Jour. Sci., vol. 49, 2 pp. (May 1920).
———. The longneck sauropod *Barosaurus*. Science, n. s., vol. 51, 528–530 (May 28, 1920).
WILLIAMS, J. W. An early ovum *in situ* in the act of aborting. Trans. Amer. Gyn. Soc. (1919).
WILLIAMSON, E. D., and L. H. ADAMS. Note on the motion of the stirrers used in optical-glass manufacture. (Papers on Optical Glass, No. 25.) Jour. Amer. Ceram. Soc., vol. 3, 671–677 (1920).
———. See ADAMS, L. H.
WILSON, E. B., and T. H. MORGAN. Chiasmatype and crossing-over. Amer. Nat., vol. 54, 193–219 (May-June 1920).
WILSON, RALPH E. The radial velocity of the greater magellanic cloud. Pub. Lick Observ., vol. 13, part 5, 187.
WISE, D. M., and W. F. WALLIS. Magnetic observations at Sobral, Brasil, May 28–30, 1919. Terr. Mag., vol. 25, No. 3 (Sept. 1920).
WRIGHT, F. E. Polarized light in the study of ores and metals. Proc. Amer. Philos. Soc., vol. 58, 401–447 (1919).
———. The measurement of the intensity of transmitted and reflected light by polarization photometers. Jour. Opt. Soc. Amer., vol. 2, 65–75 (1919).
———. Polarization and photometer prisms. Jour. Opt. Soc. Amer., vol. 2, 93–96 (1919).
———. The contrast sensibility of the eye as a factor in the resolving power of the microscope. Jour. Opt. Soc. Amer., vol. 2, 101–107 (1919).

WRIGHT, F. E. The examination of ores and metals in polarized light. Mining and Met., No. 158, Sec. 9 (1920).

———. A trigonometric computer. Jour. Wash. Acad. Sci., vol. 10, 29–31 (1920).

———. A graphical method for plotting reciprocals. Jour. Wash. Acad. Sci., vol. 10, 185–188 (1920).

———. Dispersion in optical glasses: I. (Papers on Optical Glass, No. 27.) Jour. Opt. Soc. Amer., vol. 4, 148–159 (1920).

———. Dispersion in optical glasses: II. (Papers on Optical Glass, No. 29.) Jour. Opt. Soc. Amer., vol. 4, 195–204 (1920).

———. Certain relations between chemical composition and refractivity in optical glasses. (Papers on Optical Glass, No. 31.) Jour. Amer. Ceram. Soc., vol. 3, 783–832 (1920).

WYCKOFF, RALPH W. G. The crystal structure of some carbonates of the calcite group. Amer. Jour. Sci., vol. 50, 317–360 (1920).

REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

GENTLEMEN: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution, and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1920.

During this year the Executive Committee held eleven meetings, printed reports of which have been mailed to each Trustee.

Upon the adjournment of the meeting of the Board of Trustees of December 12, 1919, the members of the Executive Committee met and organized by the election of Mr. Walcott as Chairman for 1920, and by voting that the Assistant Secretary of the Institution act as secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1919–1920, together with itemized financial statements for the same period and a summary of receipts and expenditures of the Institution to date. The President also submits a report and an outline of suggested appropriations for the year 1921. The Executive Committee hereby approves the report and the recommendations of the President as the report and recommendations of the Committee, upon the basis of which additional recommendations respecting appropriations for the year 1921 were authorized by the Committee at its meeting of November 19.

The Board of Trustees, at its meeting of December 12, 1919, appointed Messrs. Price, Waterhouse & Co., of New York, to audit the accounts of the Institution for the fiscal year ending October 31, 1920. The report of the auditor, including a balance sheet showing the assets and liabilities of the Institution on October 30, 1920, is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

A vacancy in the Board of Trustees, occasioned by the resignation of Mr. George Wharton Pepper, calls for action at the coming meeting of the Board of Trustees. In accordance with a provision of the By-Laws, nominations to fill such vacancy have been requested and have been submitted to members of the Board.

The tenures of office of Mr. Henry White and Mr. C. D. Walcott, as members of the Executive Committee, terminate at the coming annual meeting.

CHARLES D. WALCOTT, *Chairman.*
CLEVELAND H. DODGE.
WM. BARCLAY PARSONS.
STEWART PATON.
HENRY S. PRITCHETT.
ELIHU ROOT.
HENRY WHITE.
ROBERT S. WOODWARD.

November 19, 1920

Aggregate Receipts and Disbursements From Organization, January 28, 1902, to October 30, 1920.

RECEIPTS.

Interest:		
Endowment	*$15,695,714.29	
Reserve Fund	612,289.88	
Insurance Fund	65,490.08	
Colburn Fund	20,128.47	
Pension Fund	6,186.66	
		$16,399,809.38
Colburn Fund		52,015.74
Sales of Publications:		
Index Medicus	73,752.19	
Year Book	1,067.71	
Miscellaneous	94,762.01	
		169,581.91
Revertments:		
Grants	167,138.26	
Administration	10,681.53	
Unappropriated balance	15,432.09	
		193,251.88
Miscellaneous:		
Carnegie Corporation of N. Y.		
C. I. of W. ... $600,000		
Nat'l R. C. ... 150,000	750,000.00	
Insurance	5,142.01	
Pension Fund	226.00	
Sale of paper	6,452.97	
		761,820.98
Redemption and Sale of Bonds		1,395,609.37
		18,972,089.26

DISBURSEMENTS.

Investment:		
Securities	$4,970,169.52	
Collection charges	6,812.76	
Administration Building and Site	309,915.69	
		$5,286,897.97
Pension Fund		23,641.02
Insurance		22,270.94
Grants:		
Large	9,584,116.95	
Minor	1,948,805.29	
		11,532,922.24
Publication		853,309.78
National Research Council		150,000.00
Administration:		
Trustees	†47,989.86	
Executive Committee	30,702.04	
Advisory Committees:		
Honorariums, 1902–1907	11,860.00	
Travel and subsistence	4,367.41	
Salaries	512,129.15	
Shipping publications	54,963.16	
Rent, surety, telephone	32,393.06	
Equipment	16,305.59	
Postage, express	22,902.53	
Printing	‡59,950.02	
Office expenses	29,160.43	
Building and grounds:		
Supplies, janitor	28,154.67	
Fuel, light, water	10,657.95	
Organization expenses (1902)	6,991.98	
		868,527.85
		18,737,569.80
Cash in Banks		234,519.46
		18,972,089.26

* Including interest from Income and Building Fund bonds. †Travel and subsistence in connection with official meetings. ‡Including Year Books.

REPORT OF AUDITORS.

New York, *November 15, 1920.*

To the Board of Trustees,
Carnegie Institution of Washington,
Washington, D. C.

Dear Sirs: We beg to report that we have audited the accounts of the Institution for the year ended October 30, 1920.

The securities representing the investments have been exhibited to us, and we have ascertained that the income therefrom has been duly accounted for. We counted the cash on hand and verified the cash in bank with certificates from the depositaries.

Cancelled checks have been exhibited to us for all payments made during the period by the administrative office at Washington, and we have tested these payments with properly approved vouchers.

The books of the various departments were not audited by us, as these departments are audited by the bursar under authority of the Executive Committee.

The appropriations and allotments were checked with certified copies of the minutes of the Trustees and of the Executive Committee.

In accordance with the established practice of the Institution, real estate and equipment are carried at cost, and all publications on hand at their selling value, and both the unexpended appropriations and the balance of income receivable for the calendar year are taken up in the balance sheet of October 30, 1920. Securities owned are carried at original valuation or cost.

Subject to the foregoing explanation, we certify that the statements printed on pages 43 to 48 of the Year Book for 1920 are in accord with the books of the Institution and are correct.

We found the books to be accurately and carefully kept, and every facility was afforded us during the course of our audit.

Yours very truly,

(Signed) Price, Waterhouse & Co.

Balance Sheet, October 30, 1920

ASSETS.

Investments (interest bearing securities):			
Endowment		$22,119,722.55	
Colburn Fund		97,880.58	
Reserve Fund		3,071,802.13	
Insurance Fund		298,603.41	
Harriman Fund		300,000.00	
Pension Fund		93,671.25	
		25,981,679.92	
Cash awaiting investment		29,033.72	
			$26,010,713.64
Property Account:			
Real Estate and Equipment at original cost—			
Division of Administration		337,904.36	
Departments of Research		2,669,656.75	
			3,007,561.11
			29,018,274.75
Current Assets:			
Cash—			
In banks (investment accounts)	$205,485.74		
Petty cash and stamps	300.00		
	205,785.74		
Income Receivable as estimated for the year 1920:			
Balance uncollected	118,618.83		
		324,404.57	
Publications and Paper:			
Books on hand at sale price	309,654.35		
Printing paper in stock for future publications	18,867.30		
	328,521.65		
Accounts Receivable—			
Sundry bills for publications sold	3,335.38		
		331,857.03	
			656,261.60
			29,674,536.35

LIABILITIES.

Endowment and Other Funds:			
Endowment		$22,120,000.00	
Colburn Fund		98,037.59	
Reserve Fund		3,080,741.82	
Insurance Fund		310,045.74	
Pension Fund		101,888.49	
Harriman Fund		300,000.00	
			$26,010,713.64
Income Invested in Property			3,007,561.11
			29,018,274.75
Current Liabilities:			
Large Grants	$190,862.26		
Minor Grants	62,529.56		
Publications	36,178.55		
Administration	14,774.15		
		304,344.52	
Unappropriated Balance		20,060.05	
Value of Publications, Paper and Invoices		331,857.03	
			656,261.60
			29,674,536.35

Receipts and Disbursements for the Year Ending October 30, 1920.

RECEIPTS.

Interest from:		
Endowment—		
Bonds	$1,112,441.25	
Bank balance	9,316.55	
		$1,121,757.80
Reserve Fund—		
Bonds	127,091.23	
Bank balance	1,185.89	
		128,277.12
Insurance Fund—		
Bonds	13,085.99	
Bank balance	183.86	
		13,269.85
Colburn Fund—		
Bonds	4,820.30	
Bank balance	38.22	
		4,858.52
Pension Fund—		
Bonds	2,544.50	
Bank balance	1,292.49	
		3,836.99
Sales of Publications:		
Index Medicus	5,451.86	
Year book	40.50	
Miscellaneous Books	12,901.43	
		18,393.79
Revertments:		
Grants	4,088.63	
Unappropriated Fund	5,050.53	
Administration	300.	
		9,439.16
Miscellaneous:		
Carnegie Corp. of N. Y.	170,000.	
Pension Fund	223.	
Paper	673.28	
		170,899.28
		1,470,732.51
Balance, Oct. 31, 1919		428,810.29
		1,899,542.80

DISBURSEMENTS.

Investment:		
Securities	$462,810.81	
Collection charges	1,505.26	
		$464,316.07
Pension Fund:		
Annuity contribution		17,915.58
Grants:		
Large	876,437.28	
Minor	121,681.41	
		998,118.69
Publication		95,933.10
National Research Council		20,000.00
Administration:		
Trustees	4,269.47	
Executive Committee	1,852.82	
Salaries	37,733.75	
Shipping publications	7,867.30	
Surety, rent, telephone	453.53	
Equipment	591.39	
Postage, express	501.05	
Printing, paper	6,981.88	
Office, petty expense, stationery	2,149.54	
Building and grounds:		
Supplies, janitors	5,403.09	
Fuel, light, water	936.08	68,739.90
		1,665,023.34
Cash in banks		234,519.46
		1,899,542.80

Schedule of Securities.

Par Value.	SECURITIES.	Investment Value.	Total.
	Endowment.		
$21,200,000	U. S. Steel Corporation, Registered 50-year 5% Gold Bonds, Series A, B, C, D, E, F, due April 1, 1951	$21,200,000.00	
175,000	Chicago, Milwaukee & Puget Sound Railway Company, First Mortgage 4% Gold Bonds, due January 1, 1949	159,268.00	
14,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989	13,953.75	
325,000	Lehigh & Lake Erie Railroad Company, First Mortgage 4½% 50-year Gold Bonds, due March 1, 1957	331,568.30	
237,000	New York City 4½% Registered Bonds, due March 1, 1963	253,557.50	
150,000	South & North Alabama Railroad Company, Consolidated Mortgage 5% Bonds, due August 1, 1936	160,875.00	
500	United States of America Third Liberty Loan	500.00	
			$22,119,722.55
	Colburn Fund.		
20,000	Acker, Merrall and Condit Company, Debenture 6% Bonds	13,600.00	
4,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage, 4½% Bonds, due 1989	4,070.00	
8,000	Park and Tilford Company, Sinking Fund, Debenture 6% Bonds	6,400.00	
50,000	Pennsylvania Railroad Co., General Mortgage, 4½% Bonds, due June 1, 1965	51,062.50	
42,000	Pittsburg, Shawmut & Northern Railroad, First Mortgage, 4% Bonds, due February 1, 1952	4,200.00	
8,000	United States of America Second Liberty Loan of 1917	7,620.28	
5,500	United States of America Third Liberty Loan of 1918	5,291.16	
3,100	United States of America Fourth Liberty Loan of 1918	3,036.64	
2,600	United States of America Victory Liberty Loan of 1919	2,600.00	
			97,880.58
	Harriman Fund.		
100,000	Southern Pacific Company, San Francisco Terminal, First Mortgage 4% Bonds, due 1950	100,000.00	
200,000	Chicago, Burlington & Quincy R. R. Co., Illinois Division, 4% Bonds, due 1949	200,000.00	
			300,000.00
22,544,700	*Carried forward*		22,517,603.13

Schedule of Securities—continued.

Par Value.	Securities.	Investment Value.	Total.
$22,544,700	*Brought forward*		$22,517,603.13
	Insurance Fund.		
$28,000	American Telephone & Telegraph Company, 4½% Convertible Bonds	$28,978.00	
50,000	Atchison, Topeka & Santa Fe Railway Company, General Mortgage, 100-year, 4% Registered Gold Bonds, due 1995	50,056.25	
25,000	Bell Telephone Company of Canada, Debenture 5% Bonds, due April 1, 1925	24,760.00	
30,000	Chicago, Burlington & Quincy Railroad Company, General Mortgage, 4% Bonds, due March 1, 1958	28,237.50	
1,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989	995.00	
21,000	Great Northern Railway First and Refunding 4¼% Bonds, due 1961	20,944.00	
21,000	Illinois Central Railroad Company, Refunding Mortgage 4% Bonds, due November 1, 1955	19,008.75	
24,000	Pennsylvania Railroad Company, Consolidated Mortgage, 4½% Bonds, due Aug. 1, 1960	25,095.01	
4,000	United States of America Second Liberty Loan of 1917	4,000.00	
63,500	United States of America Third Liberty Loan of 1918	61,128.90	
3,000	United States of America Fourth Liberty Loan of 1918	3,000.00	
32,400	United States of America Victory Liberty Loan of 1919	32,400.00	
			298,603.41
	Reserve Fund.		
50,000	American Telephone & Telegraph Company, Collateral Trust 4% Bonds, due 1929	45,500.00	
96,000	American Telephone & Telegraph Company, 4½% Convertible Bonds	99,456.25	
100,000	Baltimore & Ohio Railroad Company, General and Refunding 5% Bonds, due 1995	102,375.00	
50,000	Central Pacific Railway Company, First Refunding Mortgage 4% Registered Gold Bonds, due 1949	48,250.00	
150,000	Chicago, Burlington & Quincy Railroad Company, General Mortgage 4% Bonds, due March 1st, 1958	141,263.75	
15,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989	14,925.00	
120,000	Chicago and North-Western General Mortgage 3½% Bonds, due November 1, 1987	100,300.00	
155,000	General Electric 5% Gold Debenture Bonds	158,213.47	
48,000	Great Northern Railway Company, First and Refunding Mortgage 4¼% Bonds, due 1961	48,109.25	
100,000	Illinois Central Railroad Company, Refunding 4% Bonds, due 1955	89,668.75	
280,000	Interborough Rapid Transit Company, First Refunding Mortgage 5% Bonds, due 1966	276,701.00	
24,011,600	*Carried forward*	1,124,762.47	22,816,206.54

Schedule of Securities—continued.

Par Value.	Securities.	Investment Value.	Total.
$24,011,600	*Brought forward*	$1,124,762.47	$22,816,206.54
	Reserve Fund—cont'd.		
50,000	Lake Shore & Michigan Southern Railway Company, Registered 25-year 4% Gold Bonds, due September 1, 1928	47,000.00	
50,000	Long Island Railroad Company, Refunding Mortgage 4% Bonds, due 1949	48,285.00	
50,000	New York, Westchester & Boston Railway Company, First Mortgage 4½% Bonds, due 1946	49,187.50	
50,000	Northern Pacific-Great Northern (Chicago, Burlington & Quincy Collateral), Joint 4% Bonds, due 1921	49,037.50	
50,000	Northern Pacific Railway Co., General Lien Railway and Land Grant 3% Bonds, due Jan. 1, 2047	33,101.25	
50,000	Oregon-Washington Railroad & Navigation Company, First and Refunding 4% Mortgage Bonds, due 1961	46,375.00	
30,000	Pennsylvania Railroad Company, General Mortgage 4½% Bonds, due June 1, 1965	29,837.50	
101,000	Pennsylvania Railroad Company, Consolidated Mortgage, 4½% Bonds, due Aug. 1, 1960	105,608.12	
100,000	Southern Pacific Railroad First Refunding Mortgage, 4% Bonds, due 1955	92,148.75	
140,000	Union Pacific Railroad Co. First Lien and Refunding 4% Bonds, due June 1, 2008	128,722.50	
112,500	United States Liberty Loan, 1st Converted 4¼s, due 1947	112,500.00	
353,500	United States of America Liberty Loan of 1917, 2d Converted	322,527.04	
419,500	United States of America Third Liberty Loan of 1918	404,728.20	
364,000	United States of America Fourth Liberty Loan of 1918	357,181.30	
120,800	United States of America Victory Liberty Loan of 1919	120,800.00	
			3,071,802.13
	Pension Fund.		
50,000	United States of America Victory Liberty Loan of 1919	50,000.00	
50,000	United States of America Second Liberty Loan of 1917	43,671.25	
			93,671.25
26,152,900			25,981,679.92

Real Estate and Equipment, Original Cost.

Administration:		
Building, site, and equipment		$337,904.36
Department of Botanical Research (September 30, 1920):		
Buildings and grounds	$36,071.08	
Laboratory and library	20,702.82	
Operating appliances	18,636.51	
		75,410.41
Eugenics Record Office (September 30, 1920):		
Library, furniture, and operating appliances	11,905.52	
Archives	45,274.49	
Buildings and land	130,526.13	
		187,706.14
Department of Experimental Evolution (September 30, 1920):		
Buildings, office, library, and grounds	128,095.58	
Laboratory apparatus	11,882.20	
Field	21,222.21	
		161,199.99
Geophysical Laboratory (September 30, 1920):		
Building, library, operating appliances	170,855.98	
Laboratory apparatus	77,224.72	
Shop equipment	10,933.36	
		259,014.06
Department of Historical Research (September 30, 1920):		
Office	2,622.97	
Library	4,083.55	
		6,706.52
Department of Marine Biology (September 30, 1920):		
Vessels	31,180.43	
Buildings, docks, furniture, and library	12,120.36	
Apparatus and instruments	8,745.30	
		52,046.09
Department of Meridian Astrometry (September 30, 1920):		
Apparatus and instruments	2,453.41	
Operating	3,332.70	
		5,786.11
Nutrition Laboratory (September 30, 1920):		
Building, office, and shop	121,303.23	
Laboratory apparatus	25,021.29	
		146,324.52
Mount Wilson Observatory (August 31, 1920):		
Buildings, grounds, road, and telephone line	191,298.30	
Shop equipment	38,649.55	
Instruments	448,374.08	
Furniture and operating appliances	136,390.00	
Hooker 100-inch reflector	561,477.79	
		1,376,189.72
Department of Terrestrial Magnetism (September 30, 1920):		
Building, site, and office	163,197.19	
Vessel and survey equipment	149,024.00	
Instruments, laboratory, and shop equipment	87,052.00	
		399,273.19
		3,007,561.11

REPORTS ON INVESTIGATIONS AND PROJECTS

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1920, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.[1]

D. T. MacDougal, Director.

The attention of the staff and collaborators has been directed to the study of fundamental problems in growth and hydration, carbohydrate metabolism and nutrition, soil-aeration effects, using some of the rarer inert gases, such as helium and argon, and to the special problems of physiology and ecology presented by the vegetation of arid regions. Detailed descriptions of the results obtained are given in the following paragraphs.

GROWTH AND HYDRATION.

Course of Growth in Trees as measured by the Dendrograph, by D. T. MacDougal.

The study and use of the dendrograph, which was designed in 1918 for the continuous recording of variations in tree trunks, have led to the improvement of this instrument to its approximate final form. Steps are being taken to render it available to other workers besides the designer and his associates. Eighteen instruments, including some differences in construction, have been operated by the designer and his collaborators as noted below, and this cooperation has yielded some valuable suggestions as to operation and improvement of the apparatus.

A weather-proof recorder and a new lever set have been tested and adopted.

The operations for the season of 1920 have included measurement of 13 species of trees by observers as given below:

Acer saccharum Marsh: New York Botanical Garden; by Dr. A. B. Stout.
Platanus occidentalis L. and *Populus deltoides* Marsh: Missouri Botanical Garden; by Professor B. M. Duggar and Mr. F. S. Walpert.
Pseudotsuga mucronata (Rafinesque) Sudworth and *Pinus ponderosa* Dougl.: Alpine Laboratory, Pikes Peak, Colorado; by Dr. F. E. Clements and Mr. Gorm Loftfield.
Picea pungens Engelm: Cottonwood Nursery, Wasatch Mountains, Utah; by Mr. C. F. Korstian.
Pinus scopulorum (Engelm.) Lemmon: Fort Valley Experiment Station, Flagstaff, Arizona; by Mr. G. A. Pearson.
Populus macdougalii Rose: Continental, Arizona; by Dr. W. B. McCallum.
Fraxinus arizonica and *Parkinsonia microphylla:* Tucson, Arizona; by Dr. H. W. Fenner and Mr. B. R. Bovee.
Citrus aurantica: Citrus Experiment Station, Riverside, California; by Professor H. S. Reed.
Quercus agrifolia Nee: two trees, Carmel, California; by D. T. MacDougal.
Pinus radiata Don.: four trees, Carmel, California; by D. T. MacDougal.

In addition to the 13 species which have been measured during the present season, a single season's records of *Fagus grandifolia* and of *Pinus chihuahuana* were secured in 1919. The reduction of these records is now under way and a technical treatment of the information obtained will probably be ready before the opening of the season in 1921.

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[1] Situated at Tucson, Arizona, and Carmel, California.

Among other things established by these records is the fact that a period of several weeks may intervene between the awakened activity of the tops of the branches and increase in diameter of the trunk, especially in the pines. These rough-barked trees show great diurnal variation which, as shown by records of the variations of the woody cylinder, may be due largely to the action of non-living tissues. Not all rough-barked trees show such marked variations, while smooth-barked trees or those with a green skin display a minimum variation.

Experiments in irrigation show that trees which have come to rest may be awakened by a renewed supply of ground-water.

Dendrographs have been used to obtain comparisons of the upper and lower parts of the trunk, concerning which but little reliable information was hitherto available.

The measurements of the variations of woody cylinders offer some opportunities for estimation of the changes in surface tension in wood cells containing water and gas-bubbles and the probable part which this may play in the ascent of sap and other purely physical phenomena.

Measurement of a Season's Growth of Trees by the Newly Designed Dendrometer, by D. T. MacDougal.

In addition to the dendrographic record as to the course and daily variations in the rate of growth of tree trunks, it is desirable to register the total amount of growth of trees under observation and of a large number of others. A separate instrument which has been designated as a dendrometer has been designed for this purpose and a number of working models constructed in our own shop have been in operation on pine and oak trees at the Coastal Laboratory during the summer of 1920.

The dendrometer utilizes the principle of a number of "plungers" or short rods arranged radially to the tree, an encircling wire anchored at one end, the other end being attached to a pivoted pointer passing through holes in the outer ends of the radial rods in such manner that the lengthening of the radii is registered by the pointer as growth takes place. In practice the plungers are the short arms of L-shaped copper bars, the long arms being thin and spring-like. The ends of the long arms are attached to a belt of galvanized-iron strip. The principal features of this design were first tested as a means of securing dendrographic measurements, but as suitable wire of low-temperature coefficient could not be procured, it was discarded.

The readings of the dendrometer are taken weeks or even months apart and may be obtained at identical temperatures. The instrument is of simple design and inexpensive construction and promises to be of some practical use in ordinary forestry operation. The readings of dendrometers showing changes in circumference form a valuable check on the results of the dendrograph, which measures changes in diameter.

Growth and the Accumulation of Reserve Material as measured in the Potato, by D. T. MacDougal.

The potato tuber is an enlargement of a portion of an underground branch of the plant. Its development and increase in size are due chiefly to the multiplication of thin-walled cells of the cortex and medulla, and accumulating carbohydrates are condensed and stored as starch in these cells during growth. In this accumulation of solid material in the cells the tuber offers contrasts with any other organs previously studied.

The course of growth in such structures may be exemplified by a summary of the record of Tuber No. 2 which was measured August 10 to September 26, 1919. The weekly increase in diameter as recorded directly by the auxograph and the calculated increase in volume may be compared in the following table:

	First week.	Second week.	Third week.	Fourth week.	Fifth week.	Sixth week.	Seventh week.	Eighth week.
Diameter (mm.)......	2.9	1.3	0.9	0.0	1.2	1	0.7	0.25
Volume (cu. mm.).....	668	395	314	0.0	549	449	296	0.37

It is to be seen that the true measure of growth of such organs is to be found in changes in volume. The two cycles of enlargement are apparent. Fifteen competing tubers on other branches reduced the supply of water and material coming to this tuber, with the result that it was brought to a standstill. No further development would have ensued had the competition not been removed. When this was done enlargement was resumed and continued for four weeks, at the end of which time a diameter of about 2 cm. had been reached.

Tubers, like all organs the growth of which has been studied, show a daily variation controlled by water-supply and water-loss. Actual enlargement is checked or canceled during the midday period, when transportation reaches the highest rate, and during the period of greatest water-deficit by the shoot.

The development of a number of tubers furnished confirmation of these and other features which will be described more fully in a technical paper in preparation.

Physical Factors in Growth as determined in the Tomato, by D. T. MacDougal.[1]

The author has previously pointed out that the tissues of animals and of the greater number of plants accumulate carbohydrates, proteins, salts, and other solids during the course of growth in such manner that the relative dry weight of an organ is least in the embryonic or

[1] From the Bulletin of the Torrey Botanical Club, vol. 47, 261–269 (1920).

earlier stages and increases progressively, so that the proportion of solid material is highest and of water lowest at maturity. The stems and leaves of succulents and such berry-like fruits as the tomato (*Lycopersicum*) have been found to reverse this relation, and melons and similar structures probably do the same. Some account of the obvious features of the growth of the tomato was given in the previous report, and a more detailed study has yielded some generalizations of value both as to the course of growth and its fundamental physics.

When we take up the facts disclosed by chemical analyses of tomatoes, five things must be taken into account in any attempt to make a physical-chemical explanation of growth, as follows: (1) the proportion of sugar, including the mucilages, in the dry material increases from 9 to 37 per cent in the stage of enlargement including the formation of the seeds; (2) the acids, which include malic, phosphoric, and citric, increase toward maturity; (3) the albumins decrease with development; (4) the ash or metallic bases increase from 4.5 to 10.75 per cent of the dry weight; and (5) the proportion of cellulose lessens as the fruit proceeds toward maturity.

The reduction of the auxographic measurements of the growth of fruits and of the swelling of living and dried sections furnishes information upon which the following conclusions may be based:

1. The rate of increase in diameter of such globose, berry-like fruits is not a correct or even approximate measure of actual growth considered as an accretion of water and solid material.

2. The time at which the greatest increase in diameter takes place may coincide with the greatest growth as exemplified in previously described observations, but the increase in thickness is not a direct index of growth in such bodies. Actual growth varies as the cube of the radius.

3. The culmination of the rate may not be reached until the fruit is in a stage approaching maturity. Then the maximum accretion generally takes place in a stage subsequent to the highest rate of increase of the diameter.

4. The internal factors which determine the rate and amount of growth of the tomato include the soluble sugars and the salts or bases which increase toward maturity, as well as the albumins and celluloses, which decrease with development, while the amino-acids, not determined, probably do not vary so widely as to affect their value as growth accelerators.

5. The conjunction of low acidity and low salt-content and sugar-content would give a set of conditions for high imbibitional swelling of a pentosan-protein plasma in the earlier stages of growth which would be capable of carrying the fruit to an enlargement of 3,000 to 4,000 per cent of the dry matter, as determined by previous experiments in the

hydration of such colloids. Otherwise expressed, imbibition would be capable of making a colloidal body like a fruit which would consist of 97.5 per cent water and 2.5 per cent solid matter.

6. The higher salt-content and acidity of older fruits would operate to lessen imbibition in the fruits, which in this stage would be high in carbohydrates.

7. The above facts support the conclusion that the distentive force in growth of young fruits is chiefly imbibition. Osmotic action may play the more important part in later stages.

8. The growth of a fruit, therefore, is a resultant of two groups of activities, one ordinarily classed as imbibitional and the other associated with osmosis and turgidity.

9. Young fruits include 1 to 4 per cent more solid material than mature ones, these bodies being representative of a type of plant structure in which the dry weight does not increase with age.

10. The amino-acids induce a greater swelling or absorption of water by the cell-masses of growing tomato fruits than takes place in weak acid solutions or in water. This fact is in agreement with, and is probably fundamental to, the accelerating effect of these substances on growth.

11. Continuous measurements of tomato fruits reveal slackened growth or shrinkage in the midday period corresponding to the time of greatest transpiration, and it is concluded that water absorption during this period is balanced by the loss from the surface, in accordance with the behavior of many other structures, such as trunks and twigs of trees, stems of sunflowers, joints of *Opuntia*, and leaves of *Mesembryanthemum*.

Components and Colloidal Behavior of Plant Protoplasm, by D. T. MacDougal and H. A. Spoehr.

The principal conclusions established by our previously described investigations which are of direct interest with relation to new results to be presented are as follows:

1. The protoplasmic mass of the active cell of the plant is a mixture of carbohydrates, chiefly in the form of pentosans and albuminous substances, with a probable very low but undetermined proportion of lipins. In addition to the mucilaginous substances of the first, freely soluble sugars may be present in the cell solutions.

2. The principal components of plasmatic masses, the mucilages and the proteins, are mutually non-interdiffusible, and hence when brought together in the cell by minute accretions or mixed in liquid form must be taken to form complex emulsions or mesh-works and to occur separately both in disperse phase and disperse medium.

3. Of the components of such a mass, the one that could be regarded as the more solid, as having the lesser attraction for molecules of water,

would tend to take position in the peripheral layer and to assume a greater density by lessening the liquid phase in the surface layer.

4. The external layer of any colloidal mass or of any layer where two masses meet has invariably a composition determined by the constitution of the impinging mass. The formation of the cellulose wall, which is first seen as a free plate between two separating protoplasts, has a structure resulting from such action. The plasma of the plant being highly carbohydrate, the external layer is consequently largely anhydride of this material. The layers added internally to the initial wall must be of the same character. Furthermore, for similar reasons, the external layer of the plasma, the semi-permeable membrane, would also be high in carbohydrate. The inclosing and boundary layers of nuclei and of all special bodies in the protoplasm would have a similar dual origin.

5. Highly proteinaceous plasmas would form external layers which, in conformity with the above, would not be cellulose or so high in carbohydrate. The chitinous skins of some animal organisms offer an inviting subject for examination in this connection.

6. In so far as these limiting layers offer resistance to the passage of substances in solution equally in both directions, or as they allow the free passage of water and resistance to substances in solution, they form an osmotic machine by the action of which pressures may be set up internal to the cell and to plasmatic or nuclear masses. The implied phenomena designated as turgidity are most marked in plant cells, where distentive forces of 40 or 50 atmospheres are found. It is to be noted also that when the two elements of a plasmatic colloid, the carbohydrate and the albumin, are unequally hydrated, as is the case in nearly all solutions, the superior increase of one element in the complex meshwork would set up something akin to osmotic pressure.

7. Hydration increases, or swelling, are the result of the combination of molecules of water with colloidal aggregates of the mass. The addition of any substance which forms combinations with the colloidal carbohydrate or protein may give systems which attract, combine with, and hold proportions of water different from those displayed when water only is present.

8. The hydration increase, or swelling of an intermeshed pentosan-protein colloid, such as we imagine protoplasm to be, involves the possibility of the unequal increase of these two main components under the influence of any substance or ion, and the measurable alterations in volume will be the resultant of the effects of such a substance or ion upon the hydration of the unlike components.

9. The pentosans are weak acids and in general their hydration capacity is lessened by hydrogen ions. Hydroxyl ions and compounds containing the amino-groups, such as may be in solutions of phenylalanin, alanin, asparagin, and glycocoll, may exert an effect by which

hydration capacity is increased above that in pure water. Mucilages derived from various sources show some differences in reactions to the solutions named while conforming to the generalizations given. Their hydration is but little affected by the presence of the common sugars in the water of suspension or dispersion.

10. The albumins and their derivatives are amphoteric, being capable of dissociating as acids or as bases. Hydration in the presence of hydrogen ions may be much greater than in water and may reach the possible maximum, while that in the presence of hydroxyl ions and of various cations may also be in excess of that in water. Gelatine, as an example of this group, shows such behavior, but has restricted hydration capacity in amino-acids, such as glycocoll. On the other hand, the swelling is proportional to the high hydrogen-ion concentration of such amino-acids as aspartic acid, which is dibasic.

11. Variations in the hydration total or volume may be ascribed to changes in the colloidal components of a plasma, to products of the resident metabolism, to the action of substances absorbed during hydration, or to fluctuations in temperature.

12. The changes in volume of a mass of colloidal material are usually not iso-diametrical during hydration. Such alterations are determined by the structure of the jelly, which may be so differentiated as to show expansion and contraction almost wholly along one axis.

13. The analysis of the implied facts has also demonstrated that growth is so essentially as to its nature and so largely as to volume a matter of hydration that the compounds which facilitate the swelling of phytocolloids and of cell-masses also facilitate or accelerate growth.

Our more recent researches have led to the consideration of the following subjects: (1) the proportions of carbohydrate and albuminous matter in a colloid of the highest hydration capacity; (2) the substances or ions of biological significance which would raise the hydration capacity of these phytocolloids to the highest limit; (3) measurement of the relative effects of some metallic bases upon a carbohydrate colloid; and (4) determination of the amplitude and continuance of alternating or repeated effects of renewed or replaced solutions.

The results of the extensive auxographic measurements furnish a basis for the summarized statements as below:

1. By the use of the pentosan, agar, as representing the acid carbohydrate and of gelatine for the amphoteric albuminous component, trials were made to ascertain what proportions of these substances would show hydration capacities of a range comparable to that of living matter. A mixture containing one part carbohydrate and three parts albuminous matter shows the highest general hydration capacity under the influence of hydrogen, hydroxyl ions, and the ions which may be derived from amino-acids. Biocolloids high in albuminous matter swell most under the action of the hydrogen ion. Biocolloids

containing 40 per cent or more carbohydrates swell most in amino-compounds. Balanced biocolloids swell most in the presence of hydroxyl ions. These reactions are parallel to those of living and dried cell-masses of plants and follow through the seasonal variations determined by chemical analyses.

2. Biocolloids of which more than a fourth is carbohydrate are highly sensitive to the action of hydrogen ions, which restrict hydration.

3. The basic histidine and glycocoll (which is slightly on the acid side of neutral) increase hydration in biocolloids containing more than 40 per cent carbohydrate. Maximum swellings of 4,300 per cent by a mixture of 1 part agar and 3 parts gelatine in acid representing a high concentration for plant juices, and of 3,930 per cent by a mixture of 2 parts agar and 3 of gelatine in histidine, are of great physiological interest. But little information concerning the presence or action of the basic amino-compounds in plants is available.

4. Glycocoll and glycocoll ester increase the swelling of agar. Glycocoll lessens swelling of gelatine, while glycocoll ester, glycocoll-ester hydrochloride, and glycocoll-hydrochloride increase it beyond that shown in distilled water.

5. The hydroxides of the strong metallic bases limit the hydration of agar according to their position in the electromotive series, the least swelling taking place under the action of the strongest base at concentrations of 0.01N with the apparent exception of rubidium. Beginning with the strongest, the series runs K, (Rb), Na, Li.

6. The various effects of barium, calcium, and strontium are not so clearly determined, and the quantitative relations of these metals are not known definitely. Hydration values of agar at 0.01N were $Sr(OH)_2$ — 815, $Ca(OH)_2$ — 860, $Ba(OH)_2$ — 900.

7. Hydration of agar in calcium hydroxide exceeds that in water at 0.0001N. Increase of hydration beyond that of water by dilute solutions of hydroxides of calcium, potassium, rubidium, potassium, sodium, and lithium is an effect we have hitherto ascribed to amino-compounds only. Excess values for aniline and ammonium hydroxide are given.

8. The incorporation of bases in agar lessens its hydration capacity in any concentration yet tested, and this is also true of biocolloids of which carbohydrates constitute more than half. In mixtures containing more gelatine, hydration capacity in acids and in hydroxides may be increased by included bases. The inclusion of a metallic base and its presentation in a hydrating solution would give different results in a colloidal or plasmatic body, such as a nucleus or chromosome.

9. The data in this article were secured chiefly by the swelling of trios of sections with a total volume of 4 to 8 cubic millimeters under the auxograph in dishes into which 25 to 30 c. c. of solution were put

and renewed at intervals of 12 and 24 hours. Such renewals were attended by accelerations in the rate and increases in the total swelling. Agar and biocolloids of agar and gelatine showed this action in a marked manner. Sections of equal parts of these two components exhibited reactions in which the exaggerated swelling resulting from renewals were partly retracted very slowly on the third day. After this the exaggeration slowly decreased and the retraction increased until the two balanced about the eighth day. The two movements continued for a total period of 67 days. It is suggested that the exaggerated swelling following a renewal of the solutions may be due to the formation of glycocoll agarate, the bulk of which might be greater than that of the agar. Diffusion of this material from the section would result in a retraction or shrinkage.

10. Plates of colloids cast on glass and prevented from shrinking in area take on a heterotropic structure which varies in agar, gelatine, and in mixtures of the two. The swelling of an agar plate is almost wholly in thickness, so that the increase of a hydrated section is denoted directly by the thickness reached. Gelatine plates prepared in the same manner may increase as much as 60 per cent in length and width while swelling. Plates of mixtures of the two swell from 6 to 16 per cent in length and width, this amount being modified by the character of the hydrating solution. These effects, which may play an important part in morphological procedure in the cell, seem to indicate a meshwork structure of biocolloids, as it does not seem possible for emulsions to be differentiated in the manner implied.

Swelling of Agar in Solutions of Amino-Acids and Related Compounds, by D. T. MacDougal and H. A. Spoehr.

The protoplasmic bodies of the cells of plants are composed chiefly of pentosans or mucilages and proteins, with an undetermined amount of lipins, while the common bases, potassium and sodium, are probably present in the form of salts of organic and inorganic acids.

The hydration or capacity of the pentosans to absorb water is such that their action doubtless plays a major role in growth and other variations in volume. Detailed study of agar as representative of these pentosans or mucilages shows that there are very few such solutions in which agar swells to a greater degree than it does in distilled water. Some substances, however, increase the hydration of agar above that attained in pure water; these are the amino-acids. The amino-compounds are of such immediate biological importance that a discussion of their action deserves special consideration, and may aid in explaining the scattered results obtained by various workers in which increased total growth and apparently catalytically accelerated actions have been obtained by the addition of certain amino-acids to culture solutions.

Agar is a carbohydrate and as such exhibits some of the properties of an exceedingly weak acid. The amino-acids are amphoteric electrolytes and therefore behave like acids toward bases and like bases toward acids. A comparative study of the swelling of agar in aqueous solutions of the simpler organic acids and their corresponding α-amino compounds showed that in the latter class of substances agar swells more than in the fatty-acid solutions. In solutions more dilute than 0.01 normal the swelling in the α-amino acids exceeds that attained in distilled water. Gelatine, on the other hand, attains its greatest swelling in solutions of the fatty acids, then in water, and less than the latter in solutions of the α-amino acids.

Further insight as to whether the increased swelling of agar in amino-acids is due to salt formation between the weak acid, agar, and the amphoteric amino-acid was sought in a study of the behavior of agar toward ammonium hydroxide and other bases. From these experiments it would appear that the stronger the base, as indicated by its position in the electromotive series, the less is the effect on the swelling of agar. Thus we have in effect: $KOH < NaOH < LiOH < C_2H_5NH_2 < NH_4OH$. In solutions of greater concentration than 0.01 normal the conditions in case of the ethyl amine and ammonium hydroxide are somewhat complicated, owing to the complexities of equilibria between dissolved NH_3 and $C_2H_5NH_2$ and their respective hydroxides.

Of great importance in experiments with these bases is the frequent renewal of the solutions in which the agar plates are swelling. Owing to the absorption of CO_2 from the air and, in case of NH_3 and $C_2H_5NH_2$, the volatilization, the strength of the solutions decreases considerably in time. If the solutions are not renewed the final swellings in all solutions are very nearly equal to that attained in water. If, however, the solutions are renewed every 12 hours very marked differences are obtained. Especially noteworthy is the fact that ammonium hydroxide in 0.001 normal concentration produces a swelling considerably in excess of water.

The following shows the relative swelling of dried agar plates at 15° C. in alkaline-hydroxide solutions renewed every 12 hours; the total swelling of the plates in water is 3,950 per cent:

Normal concentration.	Water.	NH_4OH.	$C_2H_5NH_2$.	LiOH.	NaOH.	KOH.
0.01	100	25	31	24	21	21
0.001	100	115	88	40	35	29

When the agar plates are made so as to incorporate in them the kations, K or NH_4, by originally making up the 2.5 per cent agar with 0.01 normal KOH and NH_4OH instead of with water and then drying,

similar excessive swelling of the "ammonated" agar is obtained. The "kaliated" agar swells about the same as pure agar in a solution of KOH. Swellings in solutions of ammonium chloride and ammonium acetate are not higher than those in water.

The addition of a fresh solution of ammonium hydroxide affects distinctly the subsequent swelling of the already partially hydrated agar. Thus, the increase of agar in water = 100; in 0.01 N NH_4OH = 25. If, after swelling to 25 in 0.01N NH_4OH, the hydroxide solution is replaced by water, the agar will swell further to 73. When agar plates are thus allowed to swell alternately every 12 hours in water and 0.01N NH_4OH, there is at first swelling in both NH_4OH and H_2O. As the hydration continues, the swelling in NH_4OH becomes slight and finally there is a shrinkage in the NH_4OH with a subsequent swelling again in the water. However, the total swelling thus attained greatly exceeds that in water or NH_4OH alone. Similarly, alternations with glycocoll and water also produce swellings in excess of those obtained in either one alone.

Effect of a Diminished Oxygen-Supply in the Soil on the Rate of the Growth of Roots, by W. A. Cannon.

Studies on the reaction of roots to a soil atmosphere poor in oxygen or to one having an excess of carbon dioxid, which have been reported in the Year Book,[1] have been continued and extended so that they include a number of different species for the most part not previously used. Among the species studied are *Erigeron nudum*, *Juncus* sp., *Mesembryanthemum æquilaterale*, *Opuntia versicolor*, *Potentilla anserina*, and *Salix* sp., and of cultivated plants the following: alfalfa, barley, onion (market-garden), pea, and rice. A wide range in habit as well as a great diversity in habitat is thus represented. *Juncus*, *Potentilla*, and *Salix* occur in very moist soils, if not saturated, throughout the year. *Erigeron* is found in the pine forest at Carmel and hence in sandy soil which is never saturated with water. *Mesembryanthemum* grows, escaped, at Carmel under conditions not greatly unlike those to which *Erigeron* is subjected.

In the experiments the plants were grown in glass tubes under controlled conditions so far as possible. The experimental atmosphere employed was composed of atmospheric air, to which commercial nitrogen was added, or of cylinder nitrogen alone. The latter contains about 0.5 per cent oxygen. In certain experiments commercial nitrogen was passed through alkaline pyrogallol to remove the small amount of oxygen present. The composition of the soil atmosphere, the effects of which on root-growth were observed, is as follows: 2 per

[1] Cannon, W. A., Carnegie Inst. Wash. Year Book for 1916, pp. 74, 75; Year Book for 1917 pp. 82–83; Year Book for 1918, pp. 81–83.
Free, E. E., and B. E. Livingston, Year Book for 1915, pp. 60–61.
Livingston, B. E., and E. E. Free, Year Book for 1916, p. 78.

cent oxygen, 1 per cent oxygen, 0.5 per cent oxygen, balance nitrogen, and nitrogen only.

The roots of the different species studied showed, as regards the rate of growth, a considerable diversity in reaction to a soil atmosphere containing about 2 per cent oxygen. In the case of onion sets root-growth ceased promptly and in most of the other species it was slowed to a marked degree. However, in *Juncus*, *Mesembryanthemum*, *Potentilla*, and *Salix*, and to a less degree in alfalfa, root-growth was seen to be little if any less rapid than in normal soil atmosphere. The growth-rate in the pea decreased sooner than in the barley, in which the results were to a degree inconsistent. In all instances where a diminished oxygen-supply directly affects the growth-rate, such effects are less marked when the gas is renewed daily, or passed continuously through the culture, than when it is static.

In a soil-atmosphere containing 1 per cent oxygen, root-growth in most species ceased shortly, if not promptly, after the administration of the gas. In *Juncus*, *Mesembryanthemum*, *Potentilla*, *Salix*, and in barley, however, a soil atmosphere of this composition did not appear to have an immediate effect on the rate of root-growth. In *Juncus* a fairly active rate of growth went on for 7 days, during which time the roots were continuously in 1 per cent oxygen. In the case of barley, however, the results were not wholly consistent, in that there were seen variations in the rate of growth as between different plants and in the same plant on different days, which were apparently not to be traced to the effects of the gas alone.

In a soil-atmosphere of commercial nitrogen only, root-growth continued for over 5 days in *Mesembryanthemum* and for more than 7 days in *Potentilla* and *Salix;* it was seen to continue for 13 days in rice. The effect on the rate of root-growth in barley was not observed. In many of the species studied, therefore, including alfalfa, the growth of roots was inhibited by a soil atmosphere consisting of commercial nitrogen alone. Finally, in *Juncus* root-growth was observed to continue for more than 7 days in oxygen-free soil atmosphere.

The results above summarized, therefore, confirm and extend those previously reached to the effect that different species may react differently and characteristically to a soil atmosphere consisting of nitrogen only, or of nitrogen and oxygen in known but subnormal amount. It has also been shown that different species may hold unlike relations to a soil atmosphere rich in carbon dioxid, whether the normal amount of oxygen is present or not.

From these results it appears that the rate of root-growth may be directly affected by at least two features of the composition of the soil-atmosphere, namely, the presence of carbon dioxid in excess or a deficiency of oxygen, both of which are of importance as factors in the aeration of the soil. Although it is known that in certain instances

species tolerant of a large amount of carbon dioxid are also relatively, or actually, insensitive to a total or partial deprivation of oxygen, such generalization needs support from actual experimental studies with the particular species in question. Also, whether the converse is true remains to be shown, but it has been learned, in unreported studies, that in the case of *Prosopis velutina* and *Opuntia versicolor*, at any rate, the tolerance to an excessive amount of carbon dioxid in the atmosphere of the soil of the two species is apparently about the same, but the former is less injuriously affected by a diminution in the oxygen supply *per se*. To use oxygen, therefore, in connection with carbon dioxid alone in attempts to define the aeration relation of roots is apparently not justifiable.

Anaerobic Experiments with Helium, by W. A. Cannon and E. E. Free.[1]

In the annual report of this Department for the year 1919 mention was made of experiments on deficient soil aeration, in which experiments helium was used as the diluting gas instead of the nitrogen or hydrogen commonly employed. The continuation of these experiments has confirmed the observation that nitrogen and helium do not behave exactly similarly when used as the inert gas in soil-aeration experiments. No difference is observed between the two gases when the conditions are entirely anaerobic, and no difference is observed when the gas mixtures contain an ample percentage of oxygen. The differences are encountered with nitrogen and helium, each containing small percentages of oxygen.

For instance, in order that the root of the common garden pea shall be able to grow successfully, it is necessary that the soil atmosphere contain at least 1.5 per cent of oxygen, the remainder of the atmosphere being nitrogen. However, when the soil atmosphere consists mainly of helium, a content of less than 0.5 per cent of oxygen is sufficient for the growth of the root. Similar differences have been observed in the case of the germination of peas, the production of chlorophyll by rice seedlings, the phototropic curvature of the seedlings of the sunflower, the diurnal movement of acacia and oxalis, the stigmatal movement of *Diplacus glutinosus*, and several other plant activities. In all cases the difference is of the same character, namely, that a smaller percentage of oxygen is required for the progress of the given plant activity when the diluting gas is helium than when the diluting gas is nitrogen.

It is believed that this difference is due to the fact that oxygen diffuses through helium more rapidly than through nitrogen. However, since the differences are observed not only with roots growing in the soil, but also with germinating seeds, *Diplacus* flowers, and other living material exposed to a free atmosphere, it is necessary to assume that the difference in diffusion of oxygen will be effective even in the

[1] Research Associate of the Department for six months.

absence of a medium such as the soil, which greatly hinders gas diffusion and the convectional stirring of the surrounding atmosphere. The hypothesis which suggests itself is that the diffusional relations are effective in the film of absorbed gas which doubtless blankets the surface of the living material. This hypothesis has not yet been confirmed by direct experimental evidence.

Root Adaptation to Deficient Soil Aeration, by W. A. Cannon and E. E. Free.

When a plant of the ordinary sunflower is grown in soil which is normally aerated, and is then placed under conditions in which the normal soil air is replaced by nitrogen, the roots previously developed die. New roots immediately start from the lower end of the stem and replace the previous root-system. If the plant is exposed to conditions involving only low transpiration and no serious strain on the organism, it will survive this change of root-systems and continue to live, apparently healthily, under anaerobic conditions in the soil. The anaerobic roots formed when the oxygen of the soil atmosphere is removed differ from the normal roots in being shorter, thicker, and less branching, and they are almost or completely lacking in root hairs.

A similar sequence of reactions is observed when sunflower plants are grown in aerated soil and then transferred to culture solution. All or nearly all of the roots die, but a new set of roots is formed immediately, and this new set has morphological characteristics similar to those of the roots produced in anaerobic soil. This is in line with the well-known tendency of the roots of many plants grown in water-culture to be short and thick and deficient in root hairs. It is also in line with the deficiency of root hairs on the roots of many swamp plants, and suggests that lack of root hairs may be a result or a symptom of deficient soil aeration rather than a response to a surplus of water, as has been assumed.

When plants of corn (*Zea mays*) are grown in soil with sufficient soil aeration, and the soil oxygen then removed, the roots do not die, but both the roots and the shoot cease growth for a period of several days; growth of both roots and shoot is then resumed slowly, and continues, though at a lesser rate than is the case when the soil is well aerated. This suggests that some kind of physiological readjustment of the roots to anaerobic conditions occurs when the soil oxygen is removed and is necessary to continued anaerobic existence of the roots. If this be true, the adaptation in the case of the corn root differs from that in the case of the sunflower root mainly in that the physiological changes are not accompanied by perceptible morphological modifications.

PHOTOSYNTHESIS, RESPIRATION, AND NUTRITION.

Rate of Respiration of Leaves in relation to Amino-Acid and Carbohydrate Content, by H. A. Spoehr and J. M. McGee.

In the earlier investigations on the rate of respiration of leaves it was found that other factors besides the carbohydrate-content influence the rate of carbon-dioxid emission. Of all the experiments to establish what these other factors or conditions are, the most noteworthy results have been obtained on the basis of analytical and experimental data of the relation of the amino-acid and carbohydrate-content. By means of the methods for sugar determination in very small amounts of leaf material, previously worked out in this laboratory, the Van Slyke apparatus for determination of amino-acids and precise methods for establishing the rate of carbon-dioxid emission, it has been possible to obtain a mass of data which is amenable to rational coordination. For most of the experiments mature cut leaves of *Helianthus* and *Phaseolus* were used. The principal conclusions may be summarized briefly as follows:

1. In the normal course of respiration of leaves in the dark at 24° the rate of carbon-dioxid emission decreases at a diminishing rate with time; the carbohydrate content of the leaves decreases and the amino-acid content increases. This increase of amino-acids in leaves kept in the dark was observed whether the leaves were in nutrient solutions containing nitrates or in distilled water. Under normal conditions the difference in amino-acid content of leaves between early morning and evening is not as great as between leaves taken at any time of the day and then kept in the dark for 40 hours or longer.

2. When leaves are kept in the dark with the petioles in a solution of d-glucose, the carbohydrate content remains the same or increases, depending upon temperature and the concentration of the sugar solution. The amino-acids increase. The rate of carbon-dioxid emission exhibits some remarkable variations. Thus, with a leaf of original high carbohydrate content and kept in a d-glucose solution, the rate of respiration diminishes during the first 35 hours and then gradually rises again to about its original rate. If leaves are kept in the dark for about 35 hours and then given d-glucose, there is an immediate rise in the rate of carbon-dioxid emission. This apparent secondary auto-stimulation is an important support of the theory of respiration in leaves which is being formulated on the basis of these experiments.

3. When leaves are kept in the dark with the petioles in a solution of an amino-acid, *e. g.*, glycocoll, the rate of respiration decreases gradually, the carbohydrate content decreases, and the amino-acid content increases. When given amino-acids, the rates of carbohydrate consumption and of carbon-dioxid evolution in leaves are considerably higher than without the amino-acids. When leaves are given both

d-glucose and glycocoll the primary reduction in the rate of carbon-dioxid emission, noted above under 2, is very slight, and the rate then rises gradually.

In general, then, the rate of carbon-dioxid emission of leaves is influenced not only by the amount of available carbohydrates, but by other complemental factors as well. Amino-acids exercise a stimulating effect on the respiratory activity of leaves. Thus, in order to maintain the respiratory activity at an approximately definite rate, the effect of decreasing or low carbohydrate content which results in a lowering of the respiration-rate (probably purely on the basis of the law of mass-action) can be counteracted by an increase in the amino-acid content. Similarly, high sugar and high amino-acid content result in a very high respiration-rate. However, it is apparently not a simple mathematical ratio between the carbohydrate and the amino-acid content which governs the rate of respiration.

Interrelation of Photosynthesis and Respiration, by H. A. Spoehr.

The experiments with this subject have been continued and somewhat elaborated with more precise apparatus and through a larger range of conditions. The principles as outlined in the annual report of last year have been substantiated. The respiratory activity of a chlorophyllous leaf affects fundamentally the rate of photosynthetic fixation of carbon dioxid. This relation of respiration and photosynthesis is, moreover, one of very delicate adjustment. Whether this relation is a purely chemical one or, as has been hypothesized, involves the fundamental energetics of the plant has not been definitely established. Under conditions of low energy-release through respiration photosynthetic activity is also reduced. When the leaf is deprived of oxygen and thus consumes its food material of anaerobic respiration, the amount of energy released is notably much lower than under the natural, aerobic conditions. Of great importance is the fact, which has been substantiated recently by both Warburg and Willstaetter, that under anaerobic conditions photosynthetic activity ceases. Under these conditions no intensity of light will bring about the reduction of carbon dioxid.

It has, therefore, been necessary to undertake a more searching study of the factors influencing the respiratory activity of leaves, with special attention to internal conditions affecting the energy-release and with the aim of coordinating the results thus obtained with similar experiments on the photosynthetic activity.

Reduction and Dehydration of Pentose Sugars, by H. A. Spoehr and J. W. E. Glattfeld.

Physiological-chemical investigation of plant metabolism has been directed in the main towards a study of the catabolic processes taking place in the living organism. These processes are, in general, in the

nature of hydrolysis and oxidation. A wealth of knowledge has been gained from the chemical investigations of the products of hydrolysis of the more complex plant products. The most evident chemical process of living things is, of course, the oxidation of organic food material, and great progress has been made in the chemical interpretation of these oxidation processes.

But hydrolytic and oxidative changes are by no means the only chemical changes occurring in the living organism. The reverse of these changes are very common and play an exceedingly important role in the general metabolism. Reducing reactions and dehydration and condensation syntheses must be taken into consideration in any attempt to interpret the phenomena of plant metabolism from a chemical basis. These reactions have been very generally neglected by plant physiologists. It is a remarkable fact that in protoplasm (consisting in large proportion of water and apparently organized most favorably for union with oxygen) chemical changes may take place involving the liberation of water which can be duplicated outside of the cell only by means of high temperature or by strong water-attracting substances; and similarly in protoplasm there occur reducing actions involving a high reduction potential. From chemical and physiological considerations there is reason to believe that many of the dehydration and condensation syntheses are produced not by simple taking out of water but by reduction followed by condensation and possibly oxidation. Very few such reactions have, however, as yet been produced outside the living cell.

A question of the greatest theoretical as well as practical interest is the manner in which the energy is obtained for these reducing and dehydrating changes, for such changes always involve an increase in the potential energy of the substances formed. It is now recognized that, just as in the case of the reduction reaction of the photosynthetically active leaf already noted in the annual report, these reductions and dehydrations are retarded if the respiratory activity of the plant is reduced.

Of all the substances found in plants the sugars command the center of attention in considering the various aspects of plant metabolism. All evidence points to the conclusion that sugars are the first products which accumulate in the process of photosynthesis, and they thus form the starting-point for the synthesis of the tremendous number of substances found in plants. As nothing is known as to how these reducduction and dehydration actions proceed in the plant, it is essential to gain some purely chemical information regarding the processes. Theoretically it should be possible to produce synthetically some of the most valuable plant products. Experimental investigations in this field were not pursued on account of the high cost of original raw materials. Recently abundant new sources have been found from which such material can be gained very readily. The most promising starting-point is the five-carbon atom or pentose sugar.

Dr. J. W. E. Glattfeld, of the University of Chicago, spent three months as a Research Associate at the Desert Laboratory investigating the most favorable conditions for the reduction of these sugars. He succeeded in preparing a large quantity of xylose of high purity from plant material which has no agricultural value. An extensive search for the best reducing conditions was then undertaken. Various methods were studied for the reduction of xylose to xylit, including the use of hydrogen with palladium and platinum under various conditions, the use of zinc, magnesium, iron, aluminium, and tin under manifold conditions of acidity, alkalinity, temperature, pressure, etc. In brief, however, the best results were obtained by the use of 2.5 per cent sodium amalgam. Thus, with the aid of adequate mechanical shaking devices and the proper control of the acidity of the reaction mixture, very good yields of xylit were obtained. Thus far the only dehydrating agent used was formic acid previously treated with phosphorus pentoxide. This reagent yielded a number of interesting products, the nature of which is still under investigation.

Salt Requirements of Seed Plants, by B. M. Duggar.[1]

Two extensive series of experiments designed to throw some light on the salt requirements or "mineral nutrition" of seed plants were conducted at the Coastal Laboratory during the summer of 1920. In the main these experiments constitute an entirely new aspect of this work and represent a continuation, on a larger scale in this new direction, of investigations made at the Missouri Botanical Garden in 1919–20. As a result of extensive work previously reported (Carnegie Inst. Wash. Year Book for 1919, 84–85; Ann. Missouri Bot. Garden, vol. 7, 1–49, Feb. 1920) it has been apparent to the writer that a "best" salt solution for any particular plant may be regarded as more or less analogous to an "optimum" temperature. It may be affected by many variable factors. However, in the constitution of the solution itself, while the factors of osmotic strength, hydrogen-ion concentration, and physiological balance are all important, they are at the same time variable. This variability is due to the interchange of ions and compounds between the roots and the solution with lapse of time. In a nutrient solution in which the entire quantity of all solutes is in solution, the variability in the factors mentioned is greatest, and as a rule short-time intervals or frequent renewals of such solutions, involving a very considerable amount of labor, are advised in order to secure the most favorable results. It has seemed desirable, therefore, to ascertain to what extent it might be possible or desirable to substitute for certain of the soluble salts some compounds which are "insoluble" or relatively slightly soluble. Should it be possible to use such compounds in part, or in the main, and at the same time secure the necessary concen-

[1] Research Associate of the Department for three months.

tration, balance, and reaction, the presence of the solid phase would introduce a factor tending to hold the solutions constant and at the same time to render renewals of solutions less important.

It has not yet been possible to extend the experiments over the entire range of salts which might be used, but the principle has been well established and some of the results are striking. In one or more of the various combinations the following salts have been employed: of calcium—carbonate, sulphate, tribasic phosphate, and dibasic phosphate; of magnesium—carbonate, tribasic phosphate, dibasic phosphate, and the double salt with ammonium phosphate; and of iron—phosphate(ic), citrate, oxalate, and the so-called "soluble ferric phosphate" (containing citrate). Except in the control culture solutions the only "readily soluble" salts employed were magnesium sulphate and potassium nitrate. Without introducing other complexities, there seemed to be no "insoluble" source of nitrate; but magnesium-ammonium phosphate was also used as a possible source of nitrogen. The solubility of this salt is but little more than that of magnesium carbonate.

The methods employed in the preparation of the cultures were the same as in the earlier work, except that relatively large amounts of the "insoluble" salts were used, the quantities being from 0.125 gram to 0.5 gram per culture vessel with capacity of 250 c. c., and in the series here referred to no renewal of the culture medium was made. In the case of the two soluble salts, KNO_3 and $MgSO_4$, small but measured quantities were added at intervals of 10 days or more. Control cultures were made with some of the standard solutions of soluble salts, especially the "best" solution of Shive, of my previous work, and of Tottingham, designated respectively solutions A, B, and D. These solutions were renewed as usual.

The experiments so far completed have been made with the Pacific Bluestem wheat, with a growth interval in the first series of 30 days and in the second of 39 days. In each series one or more of the cultures with certain "insoluble" salts gave yields higher than the best control, solution B; and in each case at least half a dozen combinations were higher than solution D. The other control, solution A, was unsatisfactory for this variety of wheat and will not be considered in the present discussion. In both series the same combinations of salts are among the highest, but the exact order varies, and this was expected, owing partly to differences in nitrate content. The best culture in the first series, and among the best in the second series, was one containing calcium sulphate, magnesium-ammonium phosphate, "soluble ferric phosphate," and potassium nitrate. A combination with tribasic magnesium phosphate instead of the magnesium salt in the preceding gave values almost as high. Another excellent combination, the best in the second series, consisted of dibasic calcium phosphate and iron citrate combined with small proportions of the soluble salts—mag-

nesium sulphate and potassium nitrate. Almost as good was the combination in which tribasic calcium phosphate replaced the dibasic form. All of the cultures just mentioned were not only vigorous, but also of the deepest shade of green.

Aside from the specific results just outlined, some general indications derived from this work and utilizable in further experiments may be mentioned:

1. In comparative experiments the "soluble ferric phosphate" has given results much more satisfactory than ferric phosphate. Citrate of iron may be an important constituent of the culture solution. Ferric oxalate is not satisfactory.

2. Magnesium-ammonium phosphate is not a satisfactory source of nitrogen for the variety of wheat employed, but the compound is satisfactory as a source of magnesium.

3. Using tribasic calcium phosphate as the only source of calcium, a proper balance with magnesium is obtained only when the tribasic salt of magnesium is used, or more soluble forms of magnesium may be employed if ferric citrate is used instead of the "soluble ferric phosphate."

4. Any of the insoluble salts of calcium and magnesium employed in this work will furnish under the conditions an adequate concentration of these ions for most favorable growth, and the problem is one of obtaining the requisite physiological balance.

Work is in progress to determine the relation of other plants to such combinations of salts as have been employed above. The concentration of the solutions will also be determined by the lowering of the freezing-point. The initial and final hydrogen-ion concentrations have been determined colorimetrically.

Preparation of Reagents and Amino-Acids, by H. A. Spoehr and J. M. McGee.

In the experimental work of the past three years a great deal of delay and inconvenience has been occasioned by the difficulty of procuring reliable chemicals. The situation has been growing constantly more acute; not only has it been found necessary to purify practically all chemicals, even the very simplest, but some of them have no longer been obtainable at all and have had to be prepared in the laboratory. This practice has naturally resulted in a great consumption of time and energy. Neither the larger firms of manufacturing chemists nor the committees of the various scientific bodies appointed to relieve the situation have offered any substantial encouragement, so that several investigations have had to be greatly modified or indefinitely postponed.

Amino-acids have not been procurable for some time or only at an exorbitant price and of a quality utterly unfit for physiological work. As this group of compounds is essential for a continuance of the investigations on respiration and certain phases of the work on biocolloids

and growth, it was necessary to undertake their preparation. The courtesy of Professor G. N. Lewis in extending the hospitality of the chemical laboratory of the University of California made it possible to carry on this work during the months of June, July, and part of August. Under the circumstances the best method proved to be the hydrolysis of proteinaceous material and separation of the amino-acid esters by fractional distillation under high vacuum. Excellent yields of glycocoll and alanin were obtained from Japanese raw silk. Some difficulty was encountered in obtaining high-grade gelatine, as the poorer grades yield very unsatisfactory products. However, from this source and from the silk a very good supply of glycocoll, alanin, leucin, and crude prolin was obtained which will meet immediate requirements.

PHYTOGEOGRAPHY AND ECOLOGY.

Biological and Physical Factors affecting Plants in New Habitats, by D. T. MacDougal.

The plan of the implied investigations included the establishment of small experimental areas in four places in which the environmental complexes were widely different, the introduction of species from outside localities, and the exchange of species native to the localities of the experimental plots.

Three of the experimental areas were in connected physiographic series by which one was in the coniferous forest on the crest of a range, a second in the mid-slopes among the oaks, and the third in the desert valley at the foot of the range. This arrangement was one by which the tests might be expected to yield direct information on the dissemination of the local species and on the barriers to distributional movements. In addition, all three were used to test the behavior and survival of species from distant regions in which they were habituated to different environmental conditions. The fourth plantation was located near the shore of the Pacific Ocean in a cool, equable, foggy coastal climate, at a distance of nearly 1,300 km. from the first three plantations. The observations and experiments in the coastal plantation were directed chiefly to the study of the effects of the long and cool growing season on plants from deserts, from mountain summits, and from eastern America.

The records of behavior of the separate species have been kept with adequate accuracy from the time of their introduction, which in some cases extends over a period of 14 years, and the duration of the tests is illustrated by the fact that trees of *Juglans* now producing nuts were introduced as nuts in the beginning of the experiments.

The observations have been carried to a stage in which a comprehension of climatic complexes as barriers has been gained, and a conclusive demonstration of an animal barrage has been found. The relative value of seeds and of various types of resting shoots has been notably

illustrated by the results of the observations on survivals of bulbs, tubers, corms, etc., and various departures in habit and morphogenic procedure have been induced.

The following generalizations are included in the summary of results as to the comparative values of various types of disseminules in survivals in new habitats and the receptivity of new habitats:

1. Seeds and living plants of 139 species were used in the introductions into the four locations, and the behavior of these plants has been followed during the 14-year period from 1906 to 1920.

2. Several of the above species were put in more than one plantation, bringing the total number of tests or introductions to 193. The actual number of operations by the repetition of introductions brings the total number of operations to about 250.

3. Only one survival resulted out of 10 introductions by bulbs or corms, although many of these were duplicated, suggesting that this form of the resting shoot is not well adapted to dissemination or establishment in new habitats without cultivation.

4. Of the 31 introductions of plants which assume a resting form in rhizomes and rootstocks, 8 survived.

5. Of the 55 species transferred as plants with resting shoots, 20 survived in new locations, some in more than one.

6. Of the 40 species which were carried as seeds, 12 survived in the new locations.

The following statements may be made as to the conditions of dissemination of plants and barriers to distribution:

1. The dissemination of species toward lower levels takes place with facility as the change is from low to higher temperatures, and the actual transportation of seeds or propagules would be aided by air-currents, gravity as making for earth and rock slides, and streams of water. The isolated mountain and desert complexes, however, offer a range of temperatures beyond the capacity for adaptation of all but a few species.

2. An action the reverse of this may be found in the distribution of some of the opuntias; these are preeminently characteristic of the lowlands and of the deserts, but a half-dozen species are represented in the region of the oaks as high as 1,700 meters, while one species extends beyond the oaks and is found among the pines in rocks at 2,300 meters. It was discovered, however, that animals, probably rodents or rabbits, operate a barrage against the movement of other opuntias upward on the mountain slopes, as became evident by some experimental tests in the Mohave Desert of California and by repeated introductions at the Xeromontane plantation.

3. It is rarely possible to ascribe the stoppage or restriction of a species to the direct and simple action of a single physical agency. The actual effect upon one species of defective humidity, low or high

temperatures, soil moisture, and other environic components, is dependent upon the intensity or degree of the others together with an allowance for rapidity of variation in these factors as well as time or duration of exposure. It will be advantageous to realize some of the possibilities made apparent by common observations.

Among the more important environic reactions displayed by plants used in these experiments were failure by depletion of storage organs, vigorous vegetative activity resulting in supernumerary foliar and floral organs, and disturbances of the reproductive cycle.

Finally, the following general considerations were supported by the results obtained:

Species from cool regions may be more easily established in warm places than the reverse, and montane plants may come to the seashore more easily than the plants of maritime zones may spread over a mountain.

Dissemination movements are seen to be freer from regions presenting climatic extremes to more equable climates, as is amply illustrated by the success of so many species from the Atlantic States and Arizona highlands on the Pacific seashore. Possibly the occurrence of the succulent *Opuntia* in Saskatchewan may be considered as an example of this as the predominant feature in dissemination.

Not all groups of forms move and adapt themselves to new habitats with the same facility. Thus the species characteristic of desert regions represent an extreme development toward succulence and xerophytism suitable for existence with a lessened water-supply, and the retracement of the long way of morphogenic alteration by such species is all but impossible. On the other hand, many mesophytic plants show direct or individual alterations by which they pass into arid areas and maintain themselves for extended periods.

The experiments again make it plain that the habitat in which a plant may be found or in which it may have originated may not furnish the most favorable environmental complex, as amply illustrated by the behavior of species that have become weeds. In other words, the fitness of a species for native habitat may not be so close as its fitness for other as yet untried conditions.

Hydrogen-Ion Concentration of Carmel Valley Soils, by B. M. Duggar.

It has long been recognized that the reaction of the soil or, properly, of the soil solution, is important in plant relations. Since 1909 a vast array of data has accumulated indicating the range of hydrogen-ion concentration, or pH, within which micro-organisms grow most favorably or enzymic changes occur with greatest velocity. With a degree of accuracy the methods employed have been found applicable to the soil solution, and the results of Gillespie, Plummer, Hoagland, and others have yielded important exploratory data in respect to cultivated

soils. Recently the importance of this factor in the distribution of vegetation, or in any ecological work, has been emphasized, so that measurements of the hydrogen-ion concentration of soils, particularly during the growing season, may be regarded as requiring consideration along with the measurement of any climatic or other soil factor.

Ordinarily, in humid regions one thinks of bog, peat, or muck soils as acid, and often strongly acid, while most agricultural soils are less acid, varying not infrequently from pH 4.5 to pH 7.0, with the majority from pH 5.0 to 6.0. On the other hand, the indications are that soils of arid regions are more frequently alkaline. Employing the suspension method and using the standard solutions and indicators of Clark and Lubs, I have examined about 35 samples of soil from the Carmel Valley or adjacent hills and a smaller number of samples from the Salinas and Pajaro Valleys. Unless otherwise indicated, these samples were taken from 1 to 4 inches below the surface. In all cases where clear solutions were unobtainable the determinations were made with the aid of the microcolorimeter of Duboscq. The samples from the Carmel Valley represent practically all procurable soil types and vegetation areas, including hillsides, stony terraces, or bench lands (both pasture and cultivated), rich alluvial deposits, and flats, fixed dunes near the beach, and several types of bogs.

The outstanding feature of interest is the relatively narrow range of reaction, pH 6.2 to pH 7.4. The more alkaline types were those of the lower flood-plain of the river or river-bottom, often pH 7.2, and certain adobe soils taken at a depth of a foot or more below the surface. The two bogs examined gave values respectively 6.2 and 6.6, the former from a rush-scirpus association and the latter from a willow-agrimony association. All soils from chaparral areas, terraces, and hill pastures were within the range pH 6.2 to 6.6. All determinations were made during July and August.

A Soil-Temperature Survey of the United States and Canada, by Forrest Shreve.

The reappointment of the committee on Soil Temperature of the Ecological Society of America, consisting of Forrest Shreve and Dr. Alfred E. Cameron, has given opportunity for the continuation of this project. The progress of the work is due to the faithful and interested cooperation of the men who are conducting the observations and operating thermographs at the scattered stations in the United States and southern Canada. The movement of observers to other fields of work has necessitated the discontinuance of 7 of the original series of 29 stations; 6 new stations have been secured in new localities, some of which fill large gaps in the distribution of the series. At 4 of the stations readings are being taken at more than one depth or in more than one type of soil. It has happened in several cases that observers were not able to continue their readings through the winter months, and in a few

cases the personal interests of the observers have led them to secure data from depths other than 3 inches or 12 inches, to which it had been hoped to confine all of the records. However, the data which are accumulated indicate that the results of the survey will be of such a nature as to have some value in general plant and animal ecology, as well as in agriculture, horticulture, and forestry.

The work of the committee has been confined to the recording and collating of the data from the various stations, and a preliminary publication will be prepared on the basis of the data secured in the first four years, in the hope that the observations may ultimately be extended over a longer period.

Causes of the Seasonal Changes in the Transpiration of Encelia farinosa, by Edith B. Shreve.

As was mentioned in the annual report of 1919, the desert perennial *Encelia farinosa* possesses some means of cutting down its ratio of transpiration to evaporation T/E during the months in which the aridity is increasing. The evaporative power of the air is twice as great during May and June as during the cool and more humid months of January and February, while *Encelia* loses only 1.4 times as much water per unit area in the latter months as it does in the former. The plant has two distinct types of leaves, a mesophytic form which is present during the cool months and dies when arid conditions begin, to be followed by a much smaller xerophytic form. The mesophytic form is glabrous, while the xerophytic is covered with a thick mat of long hairs. The latter type is from two to three times thicker in cross-section than the former.

Disks of uniform diameter were cut from corresponding positions in the two types of leaves and the water-loss measured under the same external conditions.

When disks of the two types of leaves are placed under the same atmospheric conditions the xerophytic type loses 1.44 times as much per unit area as does the mesophytic—a result contrary to that which might have been expected from an inspection of the leaf structures.

When the water-loss is calculated on the basis of dry weight, however, an entirely different result is obtained, for then the xerophytic type loses only 0.78 as much as the mesophytic type. This is not due to decreased water-content *per se*, for when the water-content was suddenly increased by placing branches, with leaves intact, in a moist chamber, with the cut ends in water, the disks cut from these leaves showed the same loss per gram of dry weight as did the disks from untreated leaves. Thus it is evident that the decrease in T/E with increased aridity is due to some internal change in the leaf.

As previously noted, during drought seasons, a brown liquid is present in the stems and leaves which seems to be absent during cooler

months and is more abundant in some years than in others. The influence of this sap, and of the pressed juice of leaves, on the imbibition of agar and of gelatine has been investigated. The total imbibition of water by agar was diminished by the pure juice and by the dilution used, the effect of juice from the xerophytic leaves being the greater. In the case of gelatine total imbibition was increased by the juice from the mesophytic leaves, but markedly diminished by that from the xerophytic ones. Measurement of the total acidity showed that no causative agency existed in the changes in acid content.

The influence of the juice on the retentiveness of water by agar jelly was tested by making a jelly of agar with undiluted juice. An apparatus was arranged so that an altered porous-cup atmometer could draw water simultaneously from the two kinds of jellies. The large opening of a thistle tube was covered with thin white silk and the bulb embedded in the jelly in a tall stender dish, with the tube passing through a cork and projecting above the dish. Two dishes, one containing agar made with the juice and the other with water, were connected above to the atmometer cup. Each dish with its thistle tube could be removed and weighed separately. The water-loss from the agar-water jelly was to that from the agar-juice jelly as 1.00 to 0.67. The experimental error was too great to detect an undoubted difference between the juice from the two types of leaves, but it was very clear that the juice at both seasons retarded the water-loss of agar.

Two other methods were used to test the validity of the results. In one case blocks 10 by 10 by 1 cm. were cut and allowed to lose water slowly by evaporation in a closed chamber; in the other, cubes (2 cm.) were immersed in concentrated sugar solution. In both cases the agar-juice jelly lost less than the agar-water jelly. These results were very surprising, since it had been supposed on *a priori* grounds that a substance which decreased the total imbibitional capacity of a colloidal jelly would also decrease the retention of water against an external agency, particularly if the jelly were made to contain more water than it could imbibe at the temperature under consideration. The juice contains a mixture of many substances, and it was consequently decided to withhold conclusions until a separate investigation could be made using single substances.

The effect of the juice of *Encelia farinosa* on the retention of water by agar jelly made it seem advisable to undertake a separate investigation to determine whether or not a substance which changes the imbibitional capacity of a colloidal jelly changes also its resistance to water-loss by an external agent, and, if so, what relation exists between these changes. Preliminary experiments have been made with formic acid and with tyrosin, using the arrangement of thistle tubes and atmometer cups described in a previous paragraph. The results thus far indicate that these two substances, which decrease the

imbibitional capacity of agar jelly, increase its resistance to water-loss. Definite conclusions await further experimentation.

The Changing Composition of Salton Sea Water, by A. E. Vinson and S. W. Griffin.

The analyses of the water of the Salton Sea undertaken primarily for the purpose of interpreting its action on vegetation were made annually from 1907 to 1916. Additional analyses were made in 1916 and 1919, with results as given below:

Composition of Salton Sea water, parts per 100,000.

	June 3, 1907.	June 10, 1916.	June 17, 1919.
Total solids (at 110° C.)	364.80	1647.2	2614.4
Water of occlusion and hydration	....	47.5	100.4
Sodium	111.05	528.9	833.6
Potassium	2.30	5.71	9.98
Calcium	9.95	29.85	43.5
Magnesium	6.43	27.17	43.5
Aluminum	.030	.034	None
Iron	.005	.060	None
Chlorine	169.75	787.64	1247.0
Sulphuric, SO_4	47.60	207.89	337.0
Carbonic, CO_3 (in total solids)	6.58	....	....
Carbonic, CO_3 (total)	....	11.40	11.83
Bicarbonic, HCO_3 (volumetric)	....	16.10	17.08
Silicic, SiO_4	1.41	1.21	.70
Phosphoric, PO_4	.009	Doubtful trace	....
Boric acid	....	Trace	Trace
Oxygen consumed	.093	.170	....
Nitric	.18	None	....
Nitrous	None	Trace	....

If calcium had concentrated from the beginning at the same rate as total solids there would be now 71.34 parts per 100,000 of calcium instead of 43.5 parts. Thus the equivalent of 27.84 parts per 100,000 of calcium has been lost. In this manner the 0.009 part of phosphate ion present in 1907 would now amount to 0.064 part, whereas all has apparently disappeared from solution. There should also be at present 16.49 parts per 100,000 of potassium instead of 9.98 parts, a loss of 6.51 parts.

The analyses show among other interesting facts that calcium carbonate, potassium, and phosphorus have failed to concentrate at the same rate as the total dissolved salts. After due consideration of the facts that other water from the Colorado, overflow and seepage from the irrigated districts of Imperial Valley, and highly mineralized water from springs have been adding new salts to the original body and that the analytical error in determining small amounts of potassium and phosphorus in the presence of large amounts of other compounds is

relatively great, there can be no question of the actual disappearance of these elements. The ratio of potassium to sodium slowly decreased from about 1:48 to 1:90 or more. In the early years of the existence of Salton Sea the yellow precipitate or ammonium phosphomolybdate was easily secured from 1 or 2 liters of water and actually weighed, but 3 liters of water in 1916 yielded no evidence of the presence of phosphorus.

It was shown by Jones[1] that the tufas of the Salton Sink had been deposited by algæ and that the calcium carbonate disappearing from the present Salton Sea could be accounted for by these tufas. Recently one of us determined the potassium, sodium, and phosphorus in the old massive tufa deposited from the former Blake Sea at Travertine Point, and new tufa collected in 1913 from mesquite brush submerged in the present Salton Sea. The analyses gave the following result:

	Potassium.	Sodium.	Phosphate ion.
Old tufa	0.20	0.16	0.167
Recent tufa	.19	1.27	.116

The high sodium content of the recent tufa is due to the branches being removed from the sea-water and dried without rinsing. Even then the potassium-sodium ratio is about 1 : 6, while the sea-water had a similar ratio of about 1 : 90. The fact that both potassium and phosphorus have been concentrated in the tufa needs no further proof. It may be questioned, however, as to what extent this concentration accounts for the loss of these elements from the Salton Sea water. If we assume that all the calcium lost from the water has been used in forming tufa, an approximation of the amount of phosphorus and potassium that would have accompanied it may be made.

If calcium had concentrated at the same rate as total solids there would have been present in 1919 about 71.34 parts. In like manner the 0.009 part per 100,000 of phosphate ion present in 1917 would now amount to 0.064 part. The potassium should be at present 16.49 parts per 100,000 instead of 9.98 parts, a loss of 6.51 parts.

According to an analysis of the tufa deposited from Salton Sea in 1912 (made by C. N. Catlin[2] in this laboratory), 70 per cent of calcium carbonate was present. Assuming the tufa used by Griffin also to contain 70 per cent calcium carbonate, we find the 27.84 parts per 100,000 of calcium removed from the water would require the loss of 0.115 part of phosphate ion and 0.19 part of potassium.

[1] The Salton Sea, Carnegie Inst. Wash. Pub. No. 193, 79 (1914).
[2] *Ibid.*, p. 47.

While the amount of phosphorus in the tufa is nearly double what should have been present, based on the 1907 determination, it must be remembered that the determination of so small an amount would be very uncertain under the circumstances. We may consider, therefore, that the phosphorus in the tufas represents practically all of that element lost from the water. On the contrary, the potassium found in the tufa represents only about 3 per cent of that lost from the water. With regard to the fate of the lost potassium we are forced to conclude that while a small part was fixed in the tufas, the greater part has been removed by the adsorptive action of the clay and silt sediments, probably in the manner discussed by Watson.[1]

The Vegetation of a Desert Valley, by Forrest Shreve.

In 1918 work was begun on the relation of environmental conditions to the distribution of vegetation in the Avra Valley, a poorly drained basin, or semi-bolson, lying southwest of Tucson. The work has been extended during the past year to embrace not only a characteristic section of this valley, but also a group of low volcanic hills and their outwash slopes, a portion of the flood-plain of the Santa Cruz River, and the lower ends of two extensive bajadas or "mesas."

The charting of the vegetation has now been completed over an area of 240 square miles, in which there are relatively small differences of elevation and only minor and inconstant differences in the climatic conditions. The fact that only a very small number of species of perennial plants play a dominant part in the vegetation serves to emphasize the marked differences of plant covering that characterize this small area. The object of the investigation is to determine to what extent, and in what manner, these differences result from the character of the soil, and to what extent it may be necessary to seek other causal conditions.

A map has been nearly completed showing, for this area, the five physiographic types of surface into which it is naturally divisible; (*a*) hills, with rock in place; (*b*) coarse detrital slopes; (*c*) bajadas or outwash slopes of gentle gradient; (*d*) playas or poorly drained areas subject to inundation; (*e*) flood-plains. On the basis of these physiographic regions a series of mechanical soil analyses has been begun in order to determine the extent to which particular soil types may be characteristic of each of them. A general uniformity of soil composition has been found throughout each of the areas except the coarse detrital slopes and the bajadas. In the former there is a great variation in the percentage of very coarse material. In the latter there is a striking uniformity throughout the bajada of the Sierrita Mountains, with a wide variation in the bajada derived from the Rincon and Santa Rita Mountains. An investigation of the principal physical constants of these soils, so far as they are of significance to plants, is now in progress.

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[1] Abstraction of potassium by sedimentation (thesis), University of Virginia (1913).

Further work has been inaugurated with the purpose of following the surface changes in the playas of the Avra Valley and on the bajadas of the Sierrita Mountains, in view of the importance of these changes to the vegetation. The isolated bench-marks previously used have been replaced by series of metal marks established both in the streamways and on the bajadas and playas transversely to the drainage. Semi-annual measurements at these marks will indicate the amount of erosion or deposition in the very unstable surfaces of the playa and the fluctuations in gradient and carrying power of the streamways. On the bajadas the principal interest is in securing a measure of the lateral oscillation of the streamways, which is believed to be responsible for the character of these long slopes of uniform gradient which are so characteristic of desert topography.

Ecology of the Santa Lucia Mountains, by Forrest Shreve.

The work begun in 1918 on the Santa Lucia Mountains, which skirt the coast of central California, was again taken up in the summer of 1920. The work of the first year showed some differences in the floristic composition of the vegetation in the nothern part of these mountains near Monterey and in the southern part near San Luis Obispo and Santa Margarita. From the ecological standpoint, however, there is great uniformity throughout their north and south extent and the same types of vegetation recur repeatedly. As the northern end of the range comprises the highest elevations, as well as the entire series of characteristic plant communities, more intensive work has been confined to the region north of the Arroyo Seco.

Further exploration of this portion of the range has strengthened the observation that no constant differences of vegetation exist between the seaward and landward slopes. While such communities as the redwood forest and the very open forests of digger pine (*Pinus sabiniana*) are respectively confined to these slopes, they are very far from being coextensive with them, and the main divide between the drainage into the Pacific and that into the Salinas River is in no respect a vegetational boundary. Although the known differences of rainfall on the coastal and landward sides of the range are considerable, the rainless character of the greater part of the growing season reduces the influence of the sea to the narrow coastal belt and the larger valleys which are frequently visited by fog.

On the higher elevations of the Santa Lucia Mountains may be found the Coulter pine (*Pinus coulteri*), sugar pine (*P. lambertiana*), yellow pine (*P. ponderosa*), Santa Lucia fir (*Abies venusta*), canyon live oak (*Quercus chrysolepis*), and a considerable number of shrubs and herbs, none of which is found at the lower elevations. However, there are very many trees and shrubs that occur throughout the vertical range of slightly over 5,000 feet and there are communities at the latter eleva-

tion which have a close resemblance, both floristically and vegetationally, to communities below 1,000 feet.

With the object of investigating some of the physical conditions under which these vegetational phenomena exist, a preliminary line of instrumentation was carried out in the summer of 1920. Eight stations were established for securing data on temperature, evaporation, and soil moisture, and the localities were chosen so as to determine the influence exerted on these conditions by altitude and by distance from the sea, both on the coastal and landward sides.

The temperature data secured in July and August showed an increasing daily range on passing inland from the fog belt, indicated lower minima at 1,000 feet than at 5,000 feet, and maximum temperature nearly the same at all elevations outside the fog belt. The evaporation data show a doubling of the rate on passing 10 miles inland on the seaward side of the range with only 600 feet increase of altitude and an increase to 3.5 times the coastal rate at 200 feet elevation 23 miles from the sea on the landward side of the mountains. The evaporation at 5,000 feet was found to be 50 per cent greater than at 1,000 feet and 4.5 times as great as in the fog belt. The soil moisture is low in July and August in all localities, but shows a slight increase with altitude (6.9 per cent at 1,000 feet, 7.2 per cent at 3,000 feet, 14.1 per cent at 5,000 feet), while the soil moisture in the fog belt is no greater than at the inland stations.

The few data that have been secured up to this time appear to offer ground for the explanation of the distinctive vegetational features of the coastal belt and of the lack of greater altitudinal differences of vegetation. The increase in evaporating power of the air with increase of altitude is in marked contrast to the conditions on the mountains of the interior, where the reverse is true. The ratio of evaporation to soil moisture, which has been found to be such a valuable index of the general moisture conditions for plants, affords some interesting comparisons of the conditions in the Santa Lucia Mountains and in the previously investigated Santa Catalina Mountains, near Tucson. In the former region the ratio rises from 3.5 at the coast to 14.1 at 5,000 feet, while in the latter region it falls from 50.5 at the desert base to 3.3 in the forests at 8,000 feet. So far as concerns the moisture relations of the most arid months of the year, these ratios indicate a close identity between the conditions under which the Monterey pine and its associates are living on the California coast and those experienced by the yellow pine and its associates in the mountains of Arizona.

Ecology of the Strand Vegetation of the Pacific Coast of North America, by William S. Cooper.

During the summer of 1920 the work was confined to the continuation of habitat and permanent quadrat studies begun in 1919 in the vicinity of Monterey.

Ten rain gages set out in 1919 were visited and all found intact. Data were also obtained from two lighthouses, Point Pinos and Point Sur. These 12 stations may be classified as follows:

Stations 1 to 3 represent the low sand-dune country east and northeast of Monterey; 4 to 7 the Monterey pine forest of the Monterey Peninsula and its immediate surroundings; 8 is on the summit of a mountain ridge (altitude 330 meters) between the sand-dune country of Monterey Bay and the Carmel River; 9 is in the narrow Carmel Valley between the ridge of station 8 and the Santa Lucia Mountains; 10 to 12 (north to south) are on the mountainous coast (Santa Lucia Mountains) south of the Carmel River.

Two generalizations may be made: (1) The mountains are the evident cause of the striking differences in precipitation in this limited extent of country; (2) precipitation is not a factor in the explanation of the presence of luxuriant pine forest on the Monterey Peninsula. The precipitation studies will be continued through the coming rainy season.

Atmometer studies carried on during the summer of 1919, now tabulated, show that the evaporation rate in a variety of situations on the Monterey Peninsula is decidedly less than in the oak and chaparral country east of Monterey. This factor may therefore be a partial explanation of the persistence of the pine forest on the peninsula.

In the sand-dune succession as studied in the region east and northeast of Monterey, the evaporation-rate decreases and the soil moisture increases as the succession advances toward the climax.

The quadrat studies have not yet advanced far enough to yield results of importance. Facts of interest observed after the passing of one year are the destruction of luxuriant mats of *Franseria* by sand from an active blowout; the very perceptible increase in the vegetation cover on the lee slope of a sand trail where the sand movement has practically spent itself; the increase in average radius, during the last growing season, of 1 decimeter in a plant of *Arctostaphylos pumila* 5 meters in diameter; and the absence of perceptible increase in a similar but much older plant 10 meters in diameter.

Some Structural Features of the Chlorophyll-bearing Organs of Perennials of South Australia, by W. A. Cannon.

The structure of the organs of whatever morphological nature which carry on the photosynthetic processes in perennials of the more arid portions of South Australia show striking adjustments to water and light and are of especial interest.[1] The organs which contain chlorophyll are leaves, leaf stalks (phyllodia), or stems, and notwithstanding the diverse morphological origin and relations a marked parallelism in the direction of the development of their tissues may be found. Thus the striation of the exceedingly long leaves of *Hakea multilineata*, that

[1] Compare Carnegie Inst. Wash. Year Book for 1919, pp. 90–92.

of the phyllodia of *Acacia aneura*, and others of the genus, as well as that of the ultimate branches of *Casuarina stricta*, to mention three species only, is brought about very largely by a segregation of the mechanical tissue as well as of the chlorenchyma. The distribution of the conductive tissue also contributes to the same effect. Another characteristic of such chlorophyll-bearing organs is the pronounced development of the cuticle, which often is of relatively great thickness. Stomata may or may not be present either in young or in old organs. Stomata are usually protected by a depressed position, as in grooves or furrows, by the in-rolling of leaves, or by heavy cuticle. In the last-named condition the stomata lie at the bottom of pores which, in *Hakea leucoptera*, may be intercommunicating, with the effect that stomatal chambers are formed between the stomata and the external opening of the stomatal (outer) canals.

The fact that such organs of varied morphological relations, as above referred to, exhibit a strong parallelism in the nature of the structure, as they often do, suggests on the one hand the potent influence of the impinging environment, and on the other a parallelism in capacities for adjustment on the part of the reactive organs themselves. Thus in the plants considered the chlorenchyma is usually composed of cells whose long axis is placed at right angles to the surface of the organ of which they form a part. Where exceptions occur they are usually to be associated with the presence of trichomes or other outer protective structures. But the most striking characteristic of the inner morphology of the chlorophyll-bearing organs has to do with the formation of cell-walls of relatively great thickness. This mechanical tissue may in many species serve the obvious purpose which its name implies. Thus, in *Triodia irritans* and *Hakea multilineata*, to mention no other species, the upright habit, which may be a reaction to light, is made possible through the presence of tissue of this character. But sclerenchyma is often to be found in organs where mechanical support does not appear to be of the first importance. Further, if not of universal occurrence in the chlorophyll-bearing organs of the perennials of South Australia, mechanical tissue, and other tissues with heavy cell-walls, are at any rate very generally to be found. It appears, therefore, that the formation of heavy cell-walls is closely associated with aridity—the most striking feature of the environment. This conclusion finds support in the fact that under arid conditions polysaccharids may be converted into anhydrids, or cell-wall material.[1]

[1] Carnegie Inst. Wash. Year Book for 1919, pp. 99, 100.

REPORT OF THE DEPARTMENT OF EMBRYOLOGY.[1]

George L. Streeter, Director.

During the past year a study of the correlation between weight and measurements for the human fetus at the different stages of its development has been brought to a conclusion. The ideal material for a study of the growth of the embryo and for the determination of the correlation of length, weight, and age would be normal living specimens, removed by operation at chosen intervals following a single recorded coition, in cases where there is an accurate menstrual history. Furthermore, the specimens should have come from individuals of the same age, race, and stature, whose living conditions were identical, and who had previously had a like number of children. Although these formidable requirements can be fulfilled in other mammals, they can never, of course, be completely met in man. In the latter, therefore, we must be content with conditions that can be kept as nearly constant as possible for the bulk of the available material, and for results we must rely upon mean curves taken from a large number of specimens, rather than on observations upon individual ones.

This laboratory is fortunate in being the recipient of continuous accessions of human embryos in all stages of development, thus making it possible to inaugurate a plan of systematic examination whereby the factors of fixation and the technique of weighing and measuring may be kept uniform. During the past five years, by working with these improved methods, we have accumulated data sufficient for the construction of new and more adequate curves of fetal growth and for the determining of the normal ranges of variation at different periods of development. Of all embryological material examined, 704 specimens were selected as normal and sufficiently well preserved for accurate measurements. The results derived from these have been plotted and published in the form of tables, fields, and graphs. In addition to their importance in the study of normal growth, these data promise to prove of value in the recognition of the abnormal and pathological processes that are frequently met with in aborted specimens. Moreover, since most of the selected cases were accompanied by clinical records of the menstrual age, it has been possible to construct a much more accurate age scale than has heretofore been available.

I will not describe here the particular technique employed in weighing and measuring the specimens, a full account of which is contained in the completed paper. Mention may be made, however, of two improvements in the methods of measurement which have been devised in this laboratory during the course of these investigations.

[1] Address, Carnegie Laboratory of Embryology, Johns Hopkins Medical School, Baltimore, Maryland.

In measuring the sitting height of small embryos, where it is desired to obtain readings involving fractions of a millimeter, it was found necessary to have some instrument more accurate than small calipers. No matter how careful one may be, it is not always possible to so control the caliper points that they come in perfect contact with the ends of the embryo without indenting them or without risk of injuring the

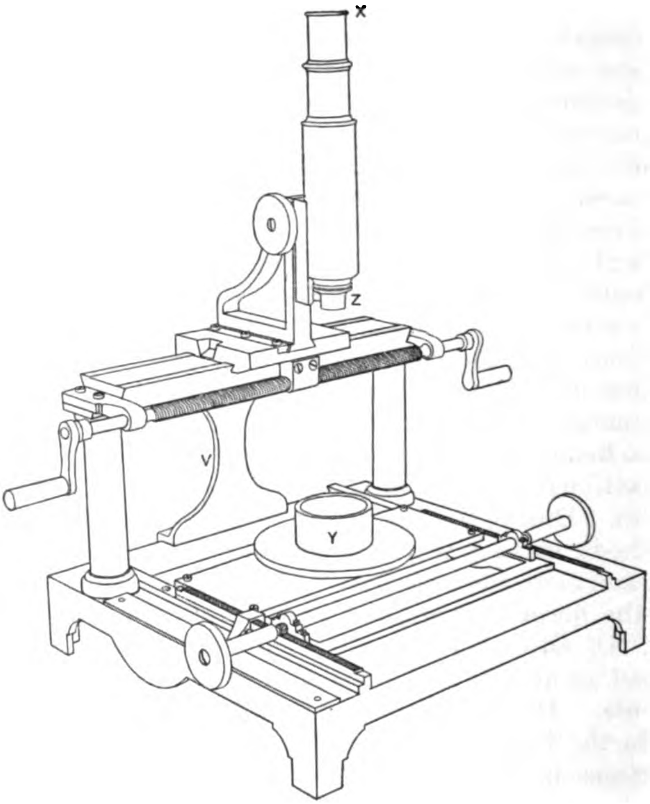

FIG. 1.—Instrument for measuring embryos. *X*, Leitz No. 0 eyepiece with cross-hairs; *Z*, 70 mm. Zeiss objective; *Y*, glass container for embryo; *V*, standard on top of which the stationary plate of the Vernier scale is mounted. Reading is made from rear of instrument.

specimen. The difficulties are increased by the fact that the measurement has to be carried on under fluid. A special measuring microscope was therefore devised (fig. 1) which has been found to adequately meet the requirements. With this apparatus one can measure with accuracy to 0.05 millimeter. For fetuses of the later months of pregnancy the methods of measurement that have prevailed are quite unsatisfactory and subject to considerable individual error. To meet this difficulty a suitable apparatus has been designed by Dr. Adolph H. Schultz; this is now in routine use in this laboratory and in the obstetrical clinic of the Johns Hopkins Hospital.

Based on the 704 normal specimens selected from our collection, the mean weight and sitting height for the end of each week of menstrual age, from the eighth week to term, are given in table 1, together with the actual and percentage weekly increments. The 704 specimens included 252 white males, 241 white females, 66 negro males, 60 negro females; other races, males, 15; females, 11; unidentified as to race or sex, 59.

TABLE 1.—*Menstrual age with mean sitting-height and weight.*

Menstrual age.	Sitting-height at end of week.	Increment in height.		Formalin weight.	Increment in weight.	
weeks.	*mm.*	*mm.*	*p. ct.*	*grams.*	*grams.*	*p. ct.*
8	23	......	....	1.1	....	....
9	31	8	26	2.7	1.6	59.3
10	40	9	22.5	4.6	1.9	41.3
11	50	10	20	7.9	3.3	41.8
12	61	11	18	14.2	6.3	44.4
13	74	13	17.6	26	11.8	45.4
14	87	13	15	45	19	42.2
15	101	14	14	72	27	37.5
16	116	15	13	108	36	33.3
17	130	14	10.8	150	42	28
18	142	12	8.4	198	48	24.2
19	153	11	7.2	253	55	21.7
20	164	11	6.7	316	63	20
21	175	11	6.3	385	69	18
22	186	11	6	460	75	16.3
23	197	11	5.6	542	82	15
24	208	11	5.3	630	88	14
25	218	10	4.6	723	93	13
26	228	10	4.4	823	100	12
27	238	10	4.2	930	107	11.5
28	247	9	3.6	1045	115	11
29	256	9	3.5	1174	129	11
30	265	9	3.4	1323	149	11.3
31	274	9	3.3	1492	169	11.3
32	283	9	3.1	1680	188	11.2
33	293	10	3.4	1876	196	10.4
34	302	9	3	2074	198	9.5
35	311	9	3	2274	200	8.8
36	321	10	3.1	2478	204	8.2
37	331	10	3	2690	212	8
38	341	10	3	2914	224	7.7
39	352	11	3.1	3150	236	7.5
40	362	10	2.8	3405	255	7 5

It is of interest to note from this table that the increment in height is greatest from the thirteenth to the seventeenth week, reaching a maximum of 15 mm. at the sixteenth week. Throughout the remainder of the fetal period the weekly increase is surprisingly constant, varying between 9 and 11 mm. The relation of the increment in height to the actual height of the specimen shows, however, a steadily decreasing percentage. The increment in weight, in contrast to the increment in height, is a constantly increasing one. The percentage increment in

weight is slightly more than twice that of the percentage increment in height and, like the latter, steadily decreases as the fetus becomes larger.

From our plotted curves it is possible to read off the weight increment for each millimeter increase in length. It is found that in fetuses under 60 mm. long it is less than 1 gram. In fetuses between 70 and 80 mm. long there is an average increase of 1 gram per millimeter. This becomes 2 grams per millimeter in fetuses between 90 and 100 mm. and 4 grams per millimeter in fetuses between 130 and 140 mm. long. In fetuses of about 200 mm. the weight increase is 10 grams per millimeter; for 300 mm. it is 20 grams per millimeter; and at term it reaches 25 grams per millimeter. Although there is this progressive increase in the actual-weight increment throughout the whole fetal period, the contrary is true for the percentage-weight increment, which progressively decreases.

It has been generally known that the length of the fetus exhibits less variation than its weight, and on this account has been regarded as a more accurate criterion of age. From the data contained in our tables it is found that the normal variation in sitting height for any given age over 40 mm. is between 8 and 10 per cent and that the normal variation in weight for any given sitting height is about 30 per cent. However, since the weekly weight increment is about three times as great in its percentage as the sitting-height increment, the difference in accuracy, when used for the determination of age, is slight. The accuracy is greater, both for weight and sitting height, in the earlier weeks of pregnancy and becomes progressively less accurate towards the later weeks, ranging from about 4 days at the fourteenth week to over 3 weeks at the thirty-fifth week. The joint use of the two determinations, however, correspondingly increases the accuracy of the age estimation.

For purposes of age determination the foot length and head size, when used alone, do not have as much value as do weight and sitting height. The head size shows considerable variation, due in part to the mechanical molding which occurs in the great majority of specimens and in part to the varying influence of formalin on the soft tissues of the scalp, which, when distended, affect the size-reading considerably more than the corresponding increase in sitting height. The foot length, as compared with the sitting height, possesses the disadvantage of being smaller and having a smaller weekly increment. Nevertheless, the head size and foot length serve as additional controls and, in case of dismembered specimens, frequently constitute the only reliable criteria for the determination of age. From an uninjured foot one can arrive fairly closely at the normal sitting height, weight, and menstrual age of the specimen by means of our curve of correlation.

I may add that as an index of head size a modulus was selected, consisting of the mean of the greatest horizontal circumference and the biauricular transverse arc. The head modulus at first is nearly equivalent to the sitting height (96 per cent). Towards the end of pregnancy it averages 16 per cent less than the sitting height. In a few outlying instances the head modulus equals or exceeds the sitting height. These are cases showing distention of the soft tissues of the scalp. If, under the usual conditions, the head modulus is greater than the sitting height, it should be regarded as abnormal. In this way we may be able to detect early cases of hydrocephalus. If, on the other hand, the head modulus is too small, we have an indication of microcephalus.

CYTOLOGY.

Our report for the year 1918 described the observations of M. R. Lewis and W. H. Lewis on the contraction phenomenon of smooth-muscle cells in hanging-drop preparations of the amnion of the chick. This method of studying the mechanism of muscle contraction has proved of great value, as it obviates the necessity of considering the complicated cell architecture of adult muscle. It brings the phenomenon within the confines of a single and quite simple cell which can be directly observed in the living condition throughout the experimentation. Further observations have since been made by M. R. Lewis on smooth-muscle cells of the amnion, and the study has been extended to include (1) the beating heart of 2 to 3-day chick embryos; (2) preparations of teased heart-muscle fibers and skeletal-muscle fibers of chick embryos; (3) marine copepods, the cross-striated muscle fibers of which could be studied while the animal remained alive; (4) isolated sarcostyles from the wing muscle of the house fly; and (5) control preparations of muscle fibers from adult dogs, cats, and turtles.

Mrs. Lewis finds that among the muscle cells of tissue-culture growth, whether originating from the amnion, the heart, or the skeletal muscles, there can always be found isolated embryonic muscle cells capable of contraction. The cytoplasm of these cells is marked by a higher refraction, but otherwise does not appear to be different from the cytoplasm of other kinds of cells in the culture. The contraction exhibited by each muscle cell varies in some details, according to the type of tissue from which it arises. The fundamental process, however, is the same for the different types of muscle cells; *i. e.*, at a certain point within the protoplasm of the cell some change takes place which results in a flow of protoplasm towards this region and a consequent thickening and shortening of the area involved. A neutralization of the active change then occurs, accompanied by a relaxation and return of the protoplasm to its normal position.

Nothing more definite as to the nature of the contraction phenomenon can be said for the present; but from these observations

it is clearly evident that contraction is not due in any way to the myofibrils, as supposed by some, since no myofibrils are present in the living cells; nor can it be due to imbibition of water at the point of contraction, for in that case there would probably be no currents of protoplasm toward the point at which the changes take place. Moreover, it is apparently not dependent upon the factors which are involved in the formation of pseudopodia, since the latter were formed by the cell, regardless of the fact that it was undergoing rhythmical contraction. Mitosis was observed in contracting cells, and it is of interest to note that during the division of the cell fibrils were not formed upon fixation.

In the report of last year I referred to the investigations of Professor W. H. Lewis, in which he showed that in the degeneration of fibroblasts in chick embryos granules and vacuoles are formed which, as they increase in number, tend to accumulate about the centriole, leaving a clear area, the centrosphere. This area may become as large as the nucleus and is usually entirely free of the granules and vacuoles. On continuing these studies Dr. Lewis finds that there are two types of degeneration, both accompanied by enlargement of the centrosphere. There is the vacuolar type, characterized by extensive vacuolization, first about the centrosphere and finally throughout the entire cytoplasm. The centrosphere is enlarged, but usually without a sharp border. The other type, the giant-centrosphere type, shows only a slight or moderate vacuolization, and the enlarged centrosphere has a sharp border and contains a single or double centriole surrounded by a clear medullary and an outer cortical zone. The cortical zone may be sharply limited or may continue out into the cytoplasmic framework between the vacuoles.

In studying the formation of the giant centrosphere it can be seen that it develops gradually around the centriole. Preceding the appearance of the centrosphere, the centriole is surrounded by degeneration granules and vacuoles; as the centrosphere develops, these are forced first to the periphery of the medullary zone and finally to the periphery of the cortical zone. The mitochondria are oriented around the centrosphere, at first radially, later concentrically. These two forms of degeneration are not sharply separated from one another and all gradations between them are found in the mesenchyme cells. In cultures from the same region sometimes one type and sometimes the other predominates. It is not yet clear whether the variations in appearance are due to the cells themselves or to differences in the cultural environment. It seems probable that the centrosphere is semi-solid, as is also the irregular cytoplasmic framework extending out from it to connect with the semi-solid peripheral layer of the cell. The vacuoles and granules occupy the more fluid part of the cytoplasm, in which are produced currents that carry the passive granules back and forth. The mitochondria lie in the cytoplasmic framework and hence their move-

ments are quite different in character from those of the granules. In the giant-centrosphere type the intervacuolar framework is not apparent, but there is a more deeply staining cytoplasm concentrated about the centrosphere, and in it lie the mitochondria in addition to the granules and vacuoles.

An interesting similarity to certain cytoplasmic inclusions in cancer cells is presented by the enlarged centrospheres in these degenerating cultures. From his observations Dr. Lewis feels justified in regarding them, as also the neutral red granules and vacuoles, as degenerative changes. In normal cell division there is a similar enlargement of the centrosphere and the etiological factors involved in the two processes are probably identical. In the normal cell, division is completed and the metabolic balance restored, whereas in the abnormal cell something prevents the completion of mitosis and death of the cell follows. Since this enlargement is found both in degenerating mesenchyme cells and in the epithelial cells of cancer, it is quite conceivable that it may not be limited to these two types, but may be found in other pathological conditions of the tissues. The fact that it occurs in the cells of tissue cultures, where we can more or less control the environment, brings within the realm of experimental solution the factors which cause this condition.

The important observations of Dr. Lewis on degeneration vacuoles in fibroblasts have been supplemented by Miss R. E. Prigosen in a study of the same phenomenon in blood cells. She has made a preliminary communication reporting the vacuolization of red blood cells in the chick and of leucocytes in human blood.

In order to test the behavior of cells under different chemical conditions, Dr. P. G. Shipley grew tissue from chick embryos in plasma and noted the reaction of the cells to various vital benzedene dyes, to colloidal silver and manganese, and to particulate foreign materials. Included with his observations is a full discussion of the course of events following vital staining of the cell—how the color enters the cells and in what state it exists in the cytoplasm. He finds that the same factors prevail where the cell stores up colloidal proteins and other finely divided materials useful in the metabolic processes of the body. His observations on neutral red granules and vacuoles are of interest, in that he does not regard them as evidences of degeneration, but rather as segregation granules and vacuoles, diverging in this respect from W. H. and M. R. Lewis, whose observations on these structures, as seen in cultures grown in salt solution, are described in this and previous reports. Shipley maintains that all foreign material, especially particulate matter, which enters the cell finds its way into these vacuoles and becomes an integral part of the contained granule. According to his view, the segregation granule, analogous to the food vacuole of protozoa, consists of the aggregated material which the cell has gathered

and stored and to which it is constantly adding albuminous and other submicrons derived from the surrounding tissue fluids, where they exist in the colloidal state.

An interesting reaction of peritoneal mesothelium to granular suspensions and laked blood has been demonstrated by Dr. R. S. Cunningham. Using cats for his experiments, he finds that these mesothelial cells show a great phagocytic activity towards injected suspensions of carbon and carmin, and where the injections are repeated for a period of several days the cells change from the characteristic flattened pavement type to the cuboidal form with large oval nuclei and an increased amount of cytoplasm. The enlarged cells continue to phagocytize the injected material. Where laked heterogeneous blood is used, the reaction is even more striking, the cells rounding up as if preparing to separate from the tissue to which they are attached.

Tissue cultures of embryonic chick liver have been made by Dr. Ruth S. Lynch. The best results were obtained from 8-day chick embryos. The liver cells migrate out from the explant in the form of a membrane, the maximum outgrowth being usually reached at 48 hours. Degeneration changes begin to appear in about 72 hours, and it is interesting to note that the degenerating cells do not show centrospheres, which are so characteristic in mesenchyme cells.

A cytological study of sympathetic nerve fibers in the chick has been made by Dr. Matsumoto, who found that with the aid of vital dyes the structure and distribution of mitochondria, granules, and vacuoles could be demonstrated in fibers cultivated *in vitro*. Neutral red was used for the granules and vacuoles, and Janus black No. 2 for the mitochondria. It was found that these dyes gave excellent results when used separately and also when made up together in the same solution.

A preliminary communication has been made by Mr. D. T. Smith regarding the formation of melanin pigment in the retina of the chick. The morphology of melanin granules in the eye was studied in a series of chicks ranging from 42 hours to 17 days of incubation. When grown in cultures it was found that these granules could be clearly distinguished from mitochondria, differing in their staining reaction and their movement within the cytoplasm of the cell. No evidence was obtained to show that they were developed from mitochondria, nor was there any evidence that they were extruded from the nucleus.

Continuing investigations previously made at the University of Liège, on the histogenesis of the sex glands, Dr. J. Firket has studied the testes of young rats and finds that the primary germ cells disappear entirely between the tenth and the fifteenth day after birth. Thus the spermatogonia can be derived only from the small epithelial cells and are in reality secondary germ cells. This is in contrast to the chick, where at least some of the primary germ cells develop into oocytes and spermatocytes.

In our last report reference was made to the study of the effect of ether vapor upon growing tissues. Since then a series of related experiments has been made (Hogue, W. H. Lewis, and M. R. Lewis) in which the environmental conditions have been changed in various ways, including the introduction of bacteria.

In order to test the effect of different concentrations of hypotonic and hypertonic solutions upon normal cells, Dr. M. J. Hogue explanted pieces from the heart tissue of chick embryos in Locke-Lewis solution containing varying amounts of sodium chloride. Two types of connective tissue are characteristic of such growths—fibroblasts and mesothelial cells. The former were selected for study, being more numerous and more sensitive to the solutions. These cells may either migrate out into the medium or grow as a reticular network, and their growth differs in these respects in the different solutions. Using hypotonic solutions of three strengths, the sodium-chloride content being respectively 0.54, 0.45, and 0.225 per cent, it was found that the weakest solution gave no growth whatever. In the intermediate solution the cells grew normally and resulted in large growths in both reticular and migratory formation, surviving as long as 12 days. In the 0.54 per cent solution the growth, as compared with the controls, was very rapid, but the cultures did not live as long. The cause for the increased migration exhibited by such preparations seems to be the search for food, the deficiency of food material in the medium acting as a stimulus. This would also account for the striking fact that in all of these cultures the cells nearest the explant were the first to die. This is explained on the ground that the search for food stimulates motility; hence the cells throw off more than the usual amount of waste matter. This becomes so great near the explant and the supply of food so scarce that the cells in this vicinity succumb, while those which have migrated out into the medium are freer from waste products, get more oxygen, and consequently live longer. This condition is just the reverse of what happens in normally grown and hypertonic cultures. In these, cell death begins at the outer edges and progresses inward towards the explant.

Three series of experiments were made with hypertonic solutions containing respectively 1.8, 1.5, and 1.2 per cent sodium chloride. In the strongest there was no growth whatever, as was the case with the weakest hypotonic solution. Moreover, when added to cultures that were doing well in the normal Locke-Lewis medium, the cells were all killed within a few hours. In a solution containing 1.5 per cent sodium chloride only 9 per cent of the cultures grew. In these, migration was not extensive and very few showed reticular growth. The cell structures as a whole appeared much the same as in normal growths. When added to cultures that were growing well in the same medium or in normal Locke-Lewis solution the cells were killed by it. Growth in a 1.2 per cent solution was very good, though slower than in the controls,

and migration was no more abundant than in hypotonic media. Both migratory and reticular growths were much the same as normal, and when stained the mitochondria and neutral-red granules were arranged as in the controls. These three hypertonic solutions show a definite gradation in their effects on the processes of the fibroblast. In Locke-Lewis solution containing 1.8 per cent sodium chloride the processes rapidly contract, become thread-like, and are withdrawn, and the cell soon dies. In the 1.5 per cent solution the processes frequently become thread-like, but some of the cells recover. In the 1.2 per cent solution the processes form and continue to move as long as the cell is alive.

Occasionally an interesting effect was observed on the part of the tissue to adapt itself to the new medium. Transparent, balloon-like structures of various sizes would arise out of the explant and lie along its margins, enlarging as if by imbibition of fluid from the tissue. Similarly, granular hills also appeared along the edges of the cultures. These were stable and lasted as long as the cultures were kept, though occasionally they broke open and poured fine granules into the surrounding medium.

Testing the effect of an active oxidizing reagent upon tissue cultures, Dr. Lewis finds that cultures treated with a weak solution of potassium permanganate (1/20,000 to 1/80,000) are usually killed in from 3 to 30 minutes. An interesting series of reactions takes place in the cytoplasm and nucleus of the dying cell. The nucleus is usually the first affected; it becomes mottled, more refractive, a membrane appears, and finally clear vacuoles are given off with a corresponding shrinkage in the size of the nucleus. Thus, pycnotic nuclei result which stain intensely in fixed material. Dr. Lewis points out that these changes have one of the essentials of mitosis; that is, a separation out of the nuclear sap and a segregation of the nuclear material into a chromosome-like mass. Shortly after the nuclear changes begin the mitochondria become irregular; they often break up into shorter lengths and later swell up into vesicles. Mitochondria stained with Janus black lose their color. In cells fixed while these changes are in progress the endoplasm becomes concentrated into a dense, deeply staining mass, either opposite to or on the same side of the nucleus as the centrosphere, the latter not being affected. As the cell dies the granules and vacuoles, if already stained with neutral red, lose their color.

Important observations have been made by M. R. Lewis concerning the effect of bacteria, especially of Bacillus typhosus, upon growing cells. Pieces of the intestine from chick embryos of 7 to 9 days' incubation were transplanted in Locke-Lewis solution, and after a normal, healthy growth was assured the cultures were inoculated with typhoid bacillus. This was done by touching a platinum wire against a growth of the organisms and then inserting it into the hanging drop. This caused rapid degeneration of the cells and death usually followed within

24 hours. The type of degeneration is very characteristic. It consists of the immediate formation of vacuoles within the cytoplasm of the cells, presenting an appearance not unlike that seen in old cultures which have not been inoculated. The vacuoles rapidly increase in size and number, to some extent coalescing, so that after a few hours the cytoplasm is crowded with them. They arrange themselves around an area corresponding to the centrosphere at one side of the nucleus. The nucleus itself does not become vacuolated.

Several kinds of bacteria were tested, some of which did not cause any vacuolization; others brought about a moderate reaction, but none of them caused the process to take place so rapidly or so extensively as did the typhoid bacillus. In normal cultures inoculated with this organism, where the cells were undergoing mitosis, both the dividing cells and the resting cells became vacuolated. The mitotic process was completed, but very few new figures were formed. When the cultures were stained with neutral red before being inoculated the vacuoles were red from their very first appearance, as is the case with degenerating cells in tissue cultures. As for the bacterial organisms, they could be seen within the vacuoles about an hour after inoculation, increasing in number and in distribution as time went on. Not all of the vacuoles, however, contained bacteria, nor were any observed in the nuclei. The number of cells containing bacteria was rather small, but was not limited to one type, the organisms being present in connective tissue, mesothelium, and endoderm. In almost every culture they remained active and increased in number.

As the vacuoles appeared almost immediately after inoculation and the bacteria not until some time later, and as many of the vacuoles contained none of the organisms, the process of vacuolization can not be regarded as the result of ingestion of the bacteria, as has been claimed by some investigators. It is of interest to note that food substances do not cause an increase in the number of vacuoles, although some foods cause a slight increase in the number of red granules. Substances like phosphorus, carbon dioxide, urea, and ammonia tend to cause the death of the cell, but they fail to result in such marked and rapid vacuolization as follows inoculation with the typhoid bacillus.

In connection with these cytological investigations reference should be made to the work of Dr. C. C. Macklin and Dr. M. T. Macklin, who have studied brain repair in the rat by the use of trypan blue. This is to some extent related to the investigation on bone repair made by the former author and mentioned in our report of 1918. The employment of vital dyes for the study of the reaction of phagocytosis or macrophages in inflamed tissues finds a particularly favorable field in the brain, since the tissue is white, contrasting well with the ingested dye, and since it contains no cells which, under normal conditions, take the dye. Aseptic wounds were produced in

the brain of rats by inserting a hot needle into the cerebrum. At varying intervals the animals were injected intraperitoneally with trypan blue, which rendered the macrophages plainly visible. Stages of repair were studied ranging from immediately after the injury to the seventy-fourth day. Other experiments were made in which a cold needle was used, and in some cases a hole was cut in the brain and bits of sterile muscle, liver, or spleen were inserted for the purpose of determining the possibility of attracting thither premacrophages which might develop into macrophages of a more trypanophilic type. Finally, injuries equivalent to a simple concussion and to a depressed fracture were produced. The authors give a complete description of the gross pathology and histopathology of the processes of inflammation and repair of the brain tissue following these various experimentally produced lesions, which account will be of the greatest importance to the neuropathologist as well as to the cytologist.

YOUNG HUMAN EMBRYOS.

The literature contains descriptions, accompanied by authentic clinical data, of 16 very young and apparently normal human ova of the presomite period. In addition there are accounts of 4 similar specimens which are probably normal, but concerning which clinical data are lacking. When one arranges all of these specimens in their respective order of development they will be found to fall into three clearly defined groups: (1) those in which the primitive groove has not yet appeared; (2) those in which there is a primitive groove but no neurenteric canal; (3) those in which the neurenteric canal and medullary groove can be definitely recognized. Through the kindness of Dr. Horace N. Mateer I have had an opportunity to study a well-preserved, normal specimen which would belong to the second of these groups and which has a probable age (fertilization) of 17 days. On account of the rarity of these very young ova and the relatively good condition of this particular specimen, a full description of it has been published. Anyone who has had occasion to study the form of these early human ova can not have failed to be impressed with the urgency of more and better material of this character. Most of the specimens thus far published are inadequate in one way or another for satisfactory study. The desired specimens must come from the operating room, and toward this end the closest cooperation should be established with clinics and hospitals.

Contained within the same chorion with the young embryo in question was an apparently still smaller twin, consisting of two minute epithelial vesicles which were embedded in the body stalk of its larger mate. Should further material confirm this as a twin, it will have an important bearing upon the problem of twin formation in man, as it represents the youngest stage yet observed. In any event, it is probable

that this twin is not altogether normal and that, if the pregnancy had not been prematurely terminated, the larger embryo would have gone on to maturity while the smaller one would have remained stationary in size as a stunted cyst, and so would have been entirely overlooked. Careful search at the placental attachment of the umbilical cord might frequently reveal the presence of similar minute epithelial vesicles representing stunted twins, and thus it is possible that the tendency towards twinning in man is even greater than is now supposed.

An embryo a little older than the above (No. 1878, Carnegie Collection), in which the second and third pairs of somites are just forming, has been described by Dr. N. W. Ingalls. It represents a stage of development which has not heretofore appeared in the literature, and thus Dr. Ingalls's paper will be eagerly read by embryologists. Perhaps the most notable feature of the external configuration of the embryo is the elevation of the head region, due jointly to the early growth of the heart and the development of the forebrain. This results in a dorsal flexure of the body. There has been much controversy as to whether this flexure, as observed in slightly older embryos, is normal or not. Judging from the form of this specimen, one would expect to find some degree of flexure as the normal occurrence.

The foregut is large and well defined. It presents a distinct buccopharyngeal membrane, the primordium of the thyroid, and the earliest indication of the first pharyngeal pockets. The midgut and hind-gut are still more or less combined. The cloacal membrane is still in the roof; thus one can not speak of a real hindgut. The allantois is very large, and Dr. Ingalls calls attention to an interesting area of contact existing between its own epithelium and the mesothelium of the body stalk. The body stalk is very large, being more bulky than the entire embryonic body. Its shape and size are due to the enormous vessels which it contains. There is a distinct amniotic duct.

By far the most interesting and important results of the study of this specimen are those which pertain to early phases of vascular development. It is possible to recognize four regions (chorion, body stalk, yolk sac, and embryo) in which blood-vessel formation occurs almost entirely independently, and in each of which the primitive vessels show different characteristics. The vascular channels show their greatest development in the body stalk, where the two umbilical arteries unite with the venous elements in forming a plexus of enormous, sac-like, anastomosing channels connected on the one hand with the chorionic plexus by irregular, slender, communicating branches, and on the other hand with the right vitelline plexus of the embryo and yolk sac by a slender channel. On the left side there is as yet no communication with the vessels of the embryo. The vessels of the body stalk contain many small, scattered masses of blood cells in varying stages of differentiation. Compared with the body stalk, the ves-

sels of the chorion are quite small. They form a rich plexus of open channels occupying the thickness of the vesicle wall. Except in the immediate neighborhood of the body stalk, they contain no formed blood elements. The vessels of the villi are abundant, to some extent forming channels, but otherwise consisting of solid cords. In many cases they exist as detached strands. In the yolk sac the vascular rudiments consist of blood islands and vessels in various stages of formation, irregularly distributed over the vesicle, being more numerous in the region of the fundus. They reach their most advanced stage of development posteriorly, near the attachment of the body stalk, where they form the vitelline plexus, providing a partial anastomosis between the vessels of the embryo and those of the body stalk. Apparently the posterior aortic antedates the omphalomesenteric connection.

As for the blood-vessels of the embryo proper, in the heart region the first pair of aortic arches exist as definite endothelium-lined channels from which minute sprouts extend forward as the internal carotid arteries, while longer channels extend caudalward as the dorsal aortæ. The latter are discontinuous, slender vessels, either solid or hollow, which extend along the margin of the neural plate. The heart is entirely plexiform, and it is of peculiar interest to note that it shows no evidence of bilaterality aside from its relations to the dorsal aortæ and the interrupted omphalomesenteric plexus.

A consideration of the vascular features presented by this embryo completely confirms the idea of the ability of the mesoderm to give rise to vascular endothelium, at least at certain stages and in man. In the body stalk and chorion the process of vessel formation by mesodermal accessions is perhaps already superseded by the direct growth and extension of preexisting vessels. In the yolk sac and the embryo both processes were still going on and it is evident that the vessels of the embryonic body were being largely formed *in loco* instead of by invasion from without.

It can be seen that a vascular system so incomplete and disconnected can not at this time play a functional role of any great importance to its possessor. The needs of the embryo as regards a circulating or diffusible medium must be met by the relatively great surface which its component parts present to the surrounding fluid, as in the yolk sac and cœlom. There can be no doubt that important nutritive material finds its way to the young embryo through the cœlom or, secondarily, through the yolk sac. We do not yet know whether the fluid within the human umbilical vesicle differs materially from that outside. One may conceive, however, that its lining endoderm plays some role in this regard. Dr. Ingalls points out that, even after the establishment of a complete, closed circulation, there still remain in the embryo wide intercellular and often avascular spaces which must function in the exchange of various fluids. Gradually, however, this

feature becomes less conspicuous, but in the last analysis the adult conditions are exactly the same and the individual cells live in the same primitive way in the tissue fluids which bathe them.

INDIVIDUAL SYSTEMS.

The study of Professor F. R. Sabin, on the origin of blood-vessels in the blastoderm of the chick, which was referred to in the report of this department for the year 1918, has after further extension been published in its final form. By the application of the tissue-culture methods of W. H. and M. R. Lewis, Dr. Sabin found it possible to make observations on living blastoderms and was able to trace the process of development of the vascular system back to its very beginning. From such preparations one can clearly demonstrate that throughout the first two days of incubation there is a continual differentiation of primitive mesenchymal cells into angioblasts, the forerunners of endothelium and red blood-cells. The process begins in the embryonic membranes, but by the stage of five somites the differentiation is in active process in the embryo itself, both the endocardium and the aorta differentiating *in situ*. In the wall of the yolk sac the differentiation is still in progress during the third and fourth days of incubation. How long the process continues and when the growth becomes restricted to the walls of previously formed vessels are still open questions. Dr. Sabin is attempting at the present time to throw light on this point by a study of the regeneration of vessels in healing wounds.

The process of differentiation of the primitive mesenchyme cells is inaugurated by a mottling of the membranes, especially of the posterior half. The mottled areas were called "blood islands" by the earlier embryologists, but Dr. Sabin's observations show that these masses form not only the vascular system but the cœlom as well. The term *blood island* is therefore restricted by her to the clumps of cells that actually develop hemoglobin and become erythrocytes. The blood islands are derived either directly from angioblasts or from the endothelial walls of the early vessels.

The exocœlom forms by a splitting apart of the two layers of cells derived from the primitive mesoderm. Blood-vessels, on the other hand, arise by a differentiation of angioblasts from this same primitive mesoderm. They form as solid syncytial masses or plexiform cords in which lumina are subsequently produced by a liquefaction of the cytoplasm and nuclei of some of the component cells. The angioblasts thus give rise to endothelium, red blood cells, and blood plasma. The peripheral portion of the angioblasts that form endothelium gives rise to other endothelial cells or to erythroblasts. These processes begin in the area opaca and gradually extend over the area pellucida to the embryo itself, each new mass of angioblasts differentiating *in situ* and joining the masses already formed. While these processes

are going on in the area pellucida they can be watched with much clearness, because here the cells are so thin that they can be focused through with ease.

In studying these early living blastoderms, Dr. Sabin has made the important observation that there are definite cycles of cell division in the vascular system, as well as in the nervous system and in the endoderm. Recognition of these cycles depends on changes in the cytoplasm, rendering it more refractive at the time just preceding cell division. The cytoplasm is more basophilic during this phase, but this reaction to dyes in fixed specimens is not so brilliant as the change in refractivity in the living form. It is not certain whether or not the mesoderm undergoes these same cycles of cell division. In the case of the vascular system in the early stages, all of the angioblasts of a given area, or all of the primitive blood cells, can be seen dividing at the same time. As a result, a certain interesting sequence may be made out in following the development of the vascular system in such preparations. Vessels first appear as solid masses at the outer margin of the area opaca. These masses form a plexus which soon becomes a plexus of hollow vessels, and while blood is forming within these marginal vessels new angioblasts differentiate in the inner half of the area opaca. Again, the same process takes place in the inner and outer margins of the area pellucida, making four different vascular zones in the embryonic membranes. By the time the chick has 10 somites, vessels have differentiated over all the membranes, there is a simple aorta, and the outer part of the system is filling up with blood. At this stage the heart begins to beat, but the beating does not propel the blood until the stage of about 16 somites, when all of the blood in the outer rim of vessels is swept into circulation and a new cycle of young blood islands starts within these same vessels. As a consequence of these cycles, which sweep across the membranes again and again, all of the phenomena, the origin of angioblasts, their transformation into vessels, and the formation of red blood cells, can often be seen in a single section of a chick in the second half of the second day.

Two investigations have been completed on the lymphatic system; one by Dr. J. R. Cash, dealing with the lymphatic drainage of the stomach, and the other by Dr. F. L. Reichert, dealing with the fate of the primary lymph sacs of the abdominal and pelvic regions. Both of these are based on injections of the lymphatic vessels in embryo pigs in various stages of development.

The work of Dr. Cash was started two years ago and is now published in completed form. He finds that the lymphatics pass to the stomach by way of its related folds of peritoneum rather than by always following the course of the blood-vessels. At 28 mm. the vessels which subsequently form the right gastric trunk have reached the stomach through the gastro-hepatic ligament. It is from this group that most

of the gastric lymphatics develop, whose distribution was completely worked out by Dr. Cash. The glands which are formed at the pyloroduodenal junction are unique. These glands prevent the injections of the duodenal lymphatics from points on the stomach, which fact may account for the failure to recognize a connection between the gastric and duodenal lymphatics.

The left gastric (splenic) trunk, which is somewhat smaller than the right, divides into two branches, one going directly to the cardiac pouch, the other passing to the hilum of the spleen. The latter branch apparently does not enter the spleen, but traverses the splenic ligament to the center of the greater curvature, where it ramifies over the anterior and posterior walls, anastomosing with vessels from the lesser curvature, thereby establishing connections with the lymphatics of the esophagus and the duodenum. No trace of an injection mass has ever been found in sections taken at the hilum of the spleen, and it is therefore to be inferred that these vessels are in no way related to the spleen, but merely use its folds of peritoneum to reach the stomach.

Growth of these lymphatics is very rapid. As early as 20 to 40 mm. the plexus is extremely dense and several layers in thickness; by 100 mm. the submucosa is completely filled by it. The vessels diminish in size as they near the pylorus and appear to end blindly, although a few of them anastomose with those of the deep plexus of the duodenum. It is of interest to note that the vessels of the esophagus are derived from two sources. Those of the lower end arise from the vessels of the periesophageal ring; these meet and anastomose with others which reach the esophagus from the bronchial plexus at the hilum of the lungs, arising primarily from the thoracic duct. Thus drainage from the esophagus takes place in two directions.

The observations made on embryos were confirmed by injections made of the stomach of adult animals. By injecting directly into the submucosa at different points, the various pathways of drainage could be readily seen by the spread of the mass through the vessels and its appearance in the adjacent nodes. The three points of invasion from the lesser curvature correspond to the chain of glands along the ascending and descending branches of the coronary and hepatic arteries. The homogeneity of the vessels, the richness of the plexuses, and the number of connections preclude the theory of any sharply defined areas by which drainage from the stomach may take place in a constant given direction. There are four general pathways: (1) lesser curvature, (2) greater curvature, (3) duodenum, and (4) esophagus.

In studying the fate of the primary lymph sacs and the development of lymph channels in the abdominal and pelvic regions, Dr. Reichert succeeded in tracing all lymphatics of these regions to three primary lymph sacs: the retroperitoneal sac, which arises ventral to the aorta, and the paired iliac sacs, which arise dorso-lateral to the

aorta. The retroperitoneal sac lies outside of the peritoneal cavity, between the Wolffian ducts and the gonads, and extends from the region of the cœliac axis to the bifurcation of the aorta. In general, it may be said that the lymphatics of all the structures situated within the abdominal cavity arise from this ventral sac. The iliac sacs are situated on either side of the midline, between the aorta and the kidneys, and are connected with the jugular sac by the thoracic duct and the cisterna chyli. In the early stages they appear to be united and form a rectangular sac between the medial surfaces of the kidneys.

From the retroperitoneal sac are given off lymphatics which drain in whole or in part the lungs, diaphragm, liver and biliary passages, stomach, small intestine, capsule of spleen, pancreas, kidneys, Wolffian bodies, gonads, Müllerian and Wolffian ducts, and umbilical cord. From the iliac sacs lymphatics drain in whole or in part the diaphragm, body wall, adrenals, kidneys, bladder, Müllerian and Wolffian ducts, umbilical cord, and the entire posterior half of the body. Only a few structures, notably the diaphragm, kidneys, and Müllerian and Wolffian ducts, which later become the excretory canals of the sex glands, receive vessels arising from both the retroperitoneal and iliac sacs.

It is of interest to note that the diaphragm is provided with a double drainage, which is probably explained by its double origin. Large lymphatic vessels from the lower lobes of the lungs extend to the pillars of the diaphragm. Other vessels from the plexus of the lesser curvature of the stomach pass directly to the diaphragm along the hepatic ligaments, anastomosing freely with the pulmonary vessels. Reichert's observations in this respect confirm those of Cash and of Cunningham, which have been previously referred to.

The early system of drainage was found by Reichert to continue into the later stages of development. Embryos of 20 cm. were injected, the injections being as nearly complete as possible, in order to determine which glands receive the drainage from the abdominal and the pelvic viscera. The primary sacs by this time have changed to lymph glands and receive afferent vessels from the same organs and structures as did the parent sac. Generally speaking, these lymph glands, as concerns position, may be divided into two groups: those ventral and ventro-lateral to the aorta, and those dorsal and dorso-lateral to the aorta. Here, as in the primary system, it may be said that the organs and structures lying within the abdominal cavity, as well as the entire posterior half of the body, drain into the glands dorsal or dorso-lateral to the aorta.

A paper on the digestion tract has been completed by Dr. P. E. Lineback, who has studied the development of the longitudinal-muscle layer of the colon in human embryos, and a preliminary paper on the digestion tract of the opossum has been published by Dr. C. H. Heuser. Dr. Heuser's work was started while he was at the Wistar Institute and

has been continued here in Baltimore. The intrauterine period of the opossum is only of 13 days' duration and the intestinal nutrition must therefore commence while the animal is still quite immature. There is thus offered an unusual opportunity to observe the factors in this process under the most primitive conditions, before there are any intestinal glands or muscle coats. The striking feature of the intestine of opossum embryos at the time of their transferral to the pouch is the presence of numerous large sinusoidal blood-vessels which closely hug the mucosa. The latter makes up nearly the whole thickness of the intestinal wall and consists of tall villi covered by columnar cells which contain characteristic masses of granules in their distal ends.

Dr. Lineback finds that in human embryos the longitudinal muscle can be recognized at the caudal end of the colon in embryos 40 mm. long and then rapidly extends towards the cœcal end. It appears first along the mesenteric line and soon spreads to incase the whole tube, forming a complete envelope before the tæniæ appear. The mesenteric portion thickens and forms the first tænia and the others are definitely formed by the time the fetus is 105 mm. long. Dr. Lineback regards the sacculations of the wall of the colon as the result of the combined action of the longitudinal and circular muscles.

The work of Dr. W. H. Lewis on the development of the skull in a 21 mm. human embryo, referred to in Year Book No. 12, was published during the past year. In the embryology of the skull there is great need for a more complete and detailed series of the various stages, showing the gradual development from the primitive membranous form to that of the adult. Dr. Lewis's excellent description of the skull of this embryo fills in one of the several gaps still existing in the sequence of published stages.

It has been anticipated that the primordial or cartilaginous skull would bear many indications of phylogenetic relationships, but apparently this is realized in only a few general features. Dr. Lewis finds that the cartilaginous skull in the embryo is as characteristically human as is the adult skull. It resembles the cartilaginous skull of other mammals not more closely than does the adult skull of man resemble the adult skull of such mammals. It is becoming more and more clear, as our knowledge of its anatomy increases, that the human embryo and its various organs are at all stages as characteristically human as are the adult body and its organs. This is what would be expected if it be true that evolution comes about through changes in the germ plasm, for in that event the changes would appear in the egg and in all the subsequent stages of ontogeny, and would modify the entire development as well as the adult. There are, however, occasional anomalies, giving fleeting indications of phylogenetic relationships that are difficult of interpretation. Such an anomaly is present in this case in the form of an occipital vertebra. The occipital hemiarches are distinct

and separated from the neighboring squamal arches by condensed mesenchyme and, in addition, they show an advanced stage of chondrification.

Observations have been made by Dr. C. L. Davis on the somites of the head in a human embryo of 20 paired somites. He finds 3 somites that can be recognized as bearing definite topographical relations to the hindbrain. This particular specimen is of especial embryological value, and Dr. Davis has in preparation a study of its general form and the anatomy of its different organs.

Three embryological studies dealing with external form have appeared during the year: the development of the external nose, by Dr. A. H. Schultz; the early recognition of sex from the external genitalia in human embryos 15 to 50 mm. long, by M. H. Spaulding; and the participation of the crus helicis in the development of the external ear, by myself. The latter two papers are in the nature of preliminary communications and will subsequently appear in more complete form.

In the first part of this report mention was made of the extensive anthropological study of the human fetus now in preparation by Dr. A. H. Schultz. One of the early results of this work has been the discovery of very marked racial differences in the form of the nose, which can be recognized as early as the beginning of the third month. Compared with the white, the negro fetus shows a greater nasal width, absolutely, as well as in relation to nasal height and facial breadth, during the entire intrauterine period. In height the nose of the white fetus is relatively larger than that of the negro. Other early differences in the shape and direction of the nostrils add to the importance of the nose in racial diagnosis.

Besides being a comparative study, Dr. Schultz's paper also furnishes accurate data on the conditions of growth of the human nose throughout fetal development. There is a decrease in the relative nasal height and relative nasal breadth as the fetus advances in age, showing that the size of the nose diminishes in relation to the size of the face. The rate of growth of the nose in both dimensions is least in the fifth and seventh months, a condition which indicates a certain rhythm of development. Growth in height of the nose is more intensive than that in breadth, which relation causes a progressive decrease in the nasal index. In breadth the nose manifests a less active growth in its upper part, between the eyes, than between the nasal wings. As development advances the former (the interocular breadth) steadily diminishes in relation to the breadth of the face. This decrease is very rapid during the third and fourth months. The relative narrowing of the nasal bridge, or the distance between the eyes, continues even after birth, but in man does not reach those extremes found in all monkeys and apes. Fetuses of the latter genera show a decrease in interocular

breadth analogous to that in human fetuses. After the fourth month of intrauterine development the nostrils, which up to this time are circular in form, gradually become elongated, their longitudinal axes converging forward in whites and occupying a transverse position in negroes. In the former race it is the anterior portion of the nostril that becomes distended as a result of the increase in the depth of the nose, while in the negro the lateral part of the nostril distends as a result of the great increase in nasal breadth. The variability in size and form of the external nose was found to be very considerable in all stages of fetal development.

Before his return to Belgium, Professor O. Van der Stricht completed a study of the arrangement and structure of the sustentacular cells and hair cells in the developing organ of Corti, and his excellent paper has appeared during the past year. His observations were made on the cat, dog, rabbit, and white rat, from the older fetal stages up to 12 days after birth. By making oblique tangential sections through the organ of Corti he was able to classify the histological arrangement of the elements of this structure and the mechanism of their shifting during the process of growth, and by a series of preparations stained to show the mitochondrial structures in the supporting cells and hair cells he was able to define the cytological nature of several structures which occur in these cells.

Since the last report a group of papers has been published dealing with the results of the work in the Army Neuro-surgical Laboratory which was conducted during the war under the direction of Professor L. H. Weed. These studies concern the central nervous system and consist for the most part of investigations on the experimental production of meningeal infections and localized traumatic abscesses of the brain tissue. Of particular importance to the anatomist are the experiments of Weed and McKibben, showing that intravenous injections of hypotonic solutions are followed by a marked and sustained rise in the pressure of the cerebrospinal fluid; on the other hand, intravenous injections of hypertonic solutions cause an initial rise in the pressure, followed at once by a marked fall, often below zero. These marked changes in the pressure of the cerebrospinal fluid were subsequently found to have a definite relation to the resultant volume of the brain. Thus, following intravenous injections of strongly hypertonic solutions, which lowered the pressure of the cerebrospinal fluid, there occurs a marked shrinkage of the brain, so that when the skull is opened the brain may be seen to have receded several millimeters from the inner surface of the skull. Conversely, the brain bulk is appreciably increased by intravenous injection of the hypotonic solutions which raise the pressure, and when openings are made in the skull the brain protrudes several millimeters through them. These changes are independent of the volume of the fluid injected and are apparently due to the

osmotic effects of the injected hypotonic and hypertonic solutions. Any future studies on the determination of the brain volume will have to take these factors into consideration.

Dr. Weed has extended his earlier observations, and those of Dr. Essick, on changes in the cells of the arachnoidal membrane of the brain, and finds that the change in morphology of these cells, when observed in full-grown and old cats, first shows itself as a localized proliferative process. Ordinarily, these cells form dense, nodular swellings well differentiated from the adjacent unchanged arachnoid membrane, which, after attaining a definite size, undergo either degeneration and calcification or more outspoken proliferation, resulting in so-called endotheliomata. In some animals, however, the proliferative process extends diffusely over the membrane. The evidence thus far indicates that the morphology of the covering cells of the arachnoidea depends not only on the physiological state of the membrane, but also upon the age of the particular animal. The complete report of this work is now in preparation.

PATHOLOGICAL STUDIES.

An interesting, very young human ovum has been studied by Professor J. Whitridge Williams. This specimen is unique in the fact that it gives us information concerning the mechanism of the process of abortion, the abortion being actually in progress at the time of the removal of the uterus. One pole of the decidua capsularis had ruptured and the corresponding pole of the ovum was extruded through the defect; the opposite pole of the ovum still retained its organic connection with the adjacent decidua by means of villi, which were in an advanced stage of hydatiform degeneration. The cœlomic cavity of the ovum was in part filled with coagulated magma, embedded in which was what appeared to be a very atrophic embryo. This specimen constitutes the youngest stage of hydatiform degeneration that has thus far been observed, and is an excellent example of inevitable abortion, the cause of which, in Dr. Williams's opinion, is to be found in a primary abnormality of the ovum.

Further evidence has been obtained by Dr. G. W. Corner that primary abnormality of the ovum, rather than faulty implantation, is in many cases the cause of pathological embryos. Dr. Corner has perfected the technique of removing early blastodermic vesicles before their attachment to the uterine mucosa (pig), and among them he has frequently found specimens under 2 weeks of age which show degenerative changes and abnormalities of growth.

Dr. Corner has also described a rare case of true bilateral hermaphroditism, with a functional ovary on one side and a testis on the other. The specimen was obtained from a pig. The uterus has two normally formed cornua, one of which ended in a normal Fallopian tube in con-

nection with a normal ovary, the latter containing four recent corpora lutea. Within the tube was found a normal ovum. The opposite cornu had a rudimentary Fallopian tube ending near the convoluted end of a Wolffian duct. The latter possessed the characteristic of an epididymis, as regards both its form and its relation to an adjoining testis. The testis was normal in structure, with the exception that germ cells were totally lacking. Dr. Corner does not attempt to explain the inhibition in development of the male germ cells in such cases.

In our report in Year Book No. 17, reference was made to the observations of Professor A. W. Meyer on the occurrence of the process of hydatiform degeneration. He showed that instead of being a rare condition, it is one of the most common forms of degeneration of the chorion and constitutes an important factor in the cause of abortion. This study has been continued by Dr. Meyer and a complete report has been published of all the instances of hydatiform degeneration found in uterine and tubal specimens of the Carnegie Embryological Collection. It is Dr. Meyer's conclusion, from the large series of cases examined by him, that this type of degeneration is usually associated with an abnormal decidua and changes suggestive of endometritis, resulting in an abnormal implantation. He is confirmed in this view by the higher incidence of hydatiform degeneration in tubal specimens, reasoning that the mucosa of the tubes forms an unfavorable place for implantation and thus leads to an abnormal nidification. He finds scant evidence that it is the result of primary germinal defects, and in this respect he deviates from the trend of the observations of Dr. Williams and Dr. Corner.

THE COLLECTION.

During the past year the collection of human embryos has been considerably increased, there having been 760 accessions between September 1, 1919, and September 1, 1920. This is the largest number we have ever received within one year. The increase is in large part due to the cooperation established between our laboratory and officers of the Health Department of Baltimore City. Through this source we are now receiving a large number of fetuses of the later months of pregnancy, which period of development has heretofore been poorly represented in the collection. We are also greatly indebted to a number of practicing physicians of Baltimore and other cities, through whose generous efforts many valuable specimens have come into our possession. Owing to the rapid increase in our material, the problem of its care and storage is becoming a pressing one. In order that it may be kept readily available to ourselves and other workers, additional space will have to be found in the near future.

The value of the collection and of our associated facilities has made itself apparent in the number of visiting investigators who have come for longer or shorter periods during the year to utilize this laboratory

in the prosecution of various researches. Professor M. H. Spaulding, of the Montana State College, has studied the development of the external genitalia in human embryos. Professor George B. Jenkins, of the State University of Iowa, has made determinations in the growth of the subdivisions of the human brain. Professor Carl L. Davis, of the University of Maryland, has studied the anatomy of a human embryo of 24 somites. Professor C. Ogawa, of the Kyoto Imperial University Medical College, Japan, has made an experimental study of the otocyst in amphibian larvæ. Professor A. W. Meyer, of the Leland Stanford Junior University, has continued his work on the pathology of human embryos. Professor Albert Kuntz, of the St. Louis University School of Medicine, has studied the sympathetic nervous system in human embryos. Dr. M. B. Wesson and Dr. F. P. Johnson, of the Brady Clinic, have studied the development of the genito-urinary organs in human embryos. Drs. L. D. Felton, L. T. Webster, and W. F. Reinhoff, from the staff of the Johns Hopkins Hospital, have worked in tissue cultures in conjunction with Professor and Mrs. Lewis. Similar work has also been followed by Professor S. Saguchi, of the Kanazawa Medical School, Japan, and by Dr. Ruth Lynch, Mr. D. T. Smith, and Miss R. E. Prigosen. Some of these studies have already been mentioned in the main body of the report; the others will be described when they are completed.

DEPARTMENT OF EXPERIMENTAL EVOLUTION AND EUGENICS RECORD OFFICE.[1]

C. B. DAVENPORT, DIRECTOR.

The present seems a fitting time to look back over the past work of the two departments reported upon herewith and to consider the plans for the future.

The Station for Experimental Evolution was started in 1904, not long after the beginning of the new era, which dates from the rediscovery of Mendel's law by De Vries, Correns, and von Tschermak in 1900. That our highest hopes for the Station have all been realized can not be affirmed; but in some respects we builded better than we knew. Thus at this Station was made the first discovery of the variation of chromosomes associated with, and inducing, a corresponding mutation of a species (the evening primrose). This lead has opened up great advances made by Professor Morgan and his colleagues. By discoveries made at this Station we see clearly that there are two types of mutations—the one due to irregularities of assortment of chromosomes and the other to changes in the chromosomes themselves; there are interchromosomal mutations and intrachromosomal mutations.

Again, studies made at this Station on the evolution of the chromosomal complex, especially in the flies, have led to the general conception that evolution has proceeded not primarily by modifications of the series of visible organisms whose evolution is the goal of our researches, but rather evolution has proceeded by changes in the "germ-plasm," the chromosomes, and that these changes have occurred in some cases apparently owing to its intrinsic properties—as radium changes into lead—and sometimes under the influence of intracellular changes, such as are induced by hybridization, and sometimes, perhaps, by extreme conditions external to the germ-cell. However it arises, once a change in the germ-plasm occurs, a corresponding change occurs in the *body* that develops under the control of that changed germ-plasm. The "giant evening primrose" is a giant just because it has, by a sort of accident, gained additional chromosomes. The polydactyl fowl, or man, has this peculiar condition because, in advance, a corresponding change in the "genes" of the chromosomes has occurred. Man is tailless, we may guess, because of a change in the gene that permits or induces a tail to develop. If that change had not occurred, man would doubtless have been a tailed "thinking being." Mankind is what it is in its physical, mental, and temperamental aspects because of the antecedent changes that occurred in the chromosomes of man's ancestors; and even inside of the "human" group, by changes in genes, numerous inheritable subgroups or "biotypes" have arisen with their physical, mental, and tem-

[1]Situated at Cold Spring Harbor, Long Island, New York.

peramental peculiarities. All these conclusions, which arise naturally and inevitably from experiments and observations in which this country has taken a leading part, are bound to revolutionize man's attitude toward himself, toward racial differences, and toward those aberrant individuals who constitute so great a "social problem."

The Eugenics Record Office has played its part in applying some of the genetic studies to man. It has first pointed out the method of inheritance of "feeble-mindedness" (1912), of epilepsy, of temperamental disorders, of eye and hair color, and of inheritance of traits in negro-white crosses.

The work of the two departments at Cold Spring Harbor is fast becoming interlocking. We have studied the distribution of twins in human families and secured an interpretation of that distribution by studies of sheep and pigs. Experimental studies of instincts and temperament in dogs will supplement the pedigree studies made on humans; and so with studies of heredity of cancer and the sex ratio.

The future direction of our work lies plain before us. First, the work of the Station for Experimental Evolution and that of the Eugenics Record Office are so akin and so interdependent that they should obviously be united in one department of Genetics, combining the two sections, each of which will continue to develop its work by the use of methods appropriate to it.

Second, the experimental work at the Station should be largely with mammals because of the probability that genetical results obtained with them will be not only of general genetical interest, but also of especial interest for the heredity of human traits. Thus, we should breed dogs for the light they will throw on heredity of instincts and temperament, rabbits (in so far as we can afford to) for the large number of characters that have already been worked out in them, mice for the light they throw on the inheritance of resistance to malignant growths, upon color factors, and upon problems of mammalian fecundity. At the same time, we should continue to develop to the utmost our genetical studies in plants and insects and, as opportunity offers, in other organisms also, in order to maintain a broad view of genetical phenomena, and because there is some of this work (as on plants) which we are especially well fitted to do.

It is also clear that progress in genetics will be made only as we consider reproduction generally—what sex is, the sex ratio, and how it is modified; differential fertilization and mortality; and the rôle of lethal or absence of vital factors.

For progress in genetics we need the assistance of the cytologist, the anatomist, the biochemist, the biometrician, and the artist. These accessory divisions of our work should not be permitted to develop independently, but only as handmaidens, of genetics. Thus we are not interested in painting or photography as such, or biometry and sta-

tistical analysis, or physiological chemistry or anatomy or microscopy *per se*, but only for the assistance they can give to our main problem.

In a department like ours it is necessary to keep an eye single to our main purpose and avoid diversion of funds to subsidiary matters, however deserving of investigation. It is necessary to plan our work more and more for a common purpose and to apply to all of our investigations the principle of cooperation.

In detail our future plans are as follows: To make a series of preliminary reconnaissance studies on pedigrees of human traits, including instincts and temperament, as particular opportunity arises. Statistical studies on human mate-selection, differential fecundity, and the sex ratio are also planned. On the experimental side it is proposed to push the study of inheritance of instincts (in dogs), of tumor-growth (in mice), of sex ratio, of the meaning of sex and sex intergrades, of fecundity, of sterility, of particular traits in animals and plants, including rabbits, mice, pigeons, bantam fowl, *Portulaca*, and *Datura*. The present status of studies on this material is more fully described in the following pages and in the publications of the department.

The main results of the year's work may now be passed briefly in review. The Director completed his assignment at Washington to the service of measuring 100,000 veterans at demobilization, and secured (1) standard measurements for the use of the Army in making uniforms (and incidentally for clothing manufacturers in general) and (2) a mass of anthropological data concerning the American population comparable to and greater in amount than that secured by Dr. B. A. Gould at the close of the Civil War. In the conduct of the present work leading anthropologists and anatomists of the country were enlisted. A discussion of these measurements, together with those made on 2,000,000 men at mobilization, is now ready for the printer.

An attempt was made by your Director to throw light upon the ancient problem of the meaning of human multiple births. A study of original records showed an inheritable tendency on the maternal side toward double ovulation, but also a nearly equal hereditary tendency toward twin production on the part of the male. Also, the method of inheritance appeared irregular. This led to a study of plural births in pigs and to the discovery (which proved to be only the confirmation of a discovery made by Hammond in 1914) that an important proportion of fetuses fail of full development *in utero*, probably because of lack of vital factors, while another fairly large percentage of eggs ovulated fail (even under favorable conditions) of fertilization. The proportion of these failures will be less, the more active, abundant, and freer from lethal factors the sperm is. Fathers of twins, experience indicates, belong to exceptionally fertile strains. Thus it comes about that fathers of twins are about as apt to belong to twin-producing strains as mothers of twins, and that twins depend on constitutional, hereditary factors on both sides of the house.

A second discovery of importance has recently been made here by Blakeslee and Belling, namely, that some of the irregular breeding behavior of the jimson weed (*Datura*) is due to irregularity of chromosome-division in cell-division, resulting in extra chromosomes in some gametes and a deficiency in others. This behavior is like that discovered by Miss Lutz in the primroses at this Station 13 years ago, which was the starting-point for the great development of our knowledge of the relation between somatic mutations and chromosome variation. The recent discovery establishes that there are two forms of mutations: one due to extrachromosomal changes or, better, changes in number of chromosomes, and one due to intrachromosomal changes, to changes in the genes.

A third capital discovery is that in a strain of mice susceptible to a particular tumor the susceptibility is not only found to be hereditary, but it is shown that the hereditary factors are probably 4, though possisibly 3 or 5 in number. This discovery makes much more definite the previously known fact of inheritance of cancer in mice, and gives an explanation of the failure to find a *simple* Mendelian explanation of inheritance of cancer in man. The inheritance is Mendelian, but there are many factors and not merely a single factor involved.

A fourth matter, whose study is now completed, was described in a preliminary way in last year's report. It is the demonstration that the effects of alcoholization of breeding rats show themselves in the grandchildren of such rats. Not, indeed, in the gross fashion described by Stockard in the case of his guinea-pigs, but by a certain stupidity or inability to learn and take advantage of experience. No other experiment of this sort approaches in careful control this series of MacDowell. One may confidently assert, therefore, that the deleterious influence of alcoholism on even remote progeny has been proved.

Again, there has been demonstrated by Riddle a chemical difference between male and female pigeon embryos, inasmuch as relatively more female than male embryos withstand a diminished oxygen pressure, indicating that they have a lower metabolism than male embryos. Thus, the fundamental difference in metabolism of the two sexes has been demonstrated for pigeons in their germinal, embryonic, and adult stages.

Finally, the theory of lethal, or loss of vital, factors has been extended to human heredity by Dr. Little, who finds clear evidence of sex-linked lethal factors in color-blind and hemophilic (bleeding) families, in consequence of which there is a larger proportion of males that are color-blind than would otherwise be expected.

EXPERIMENTAL EVOLUTION.

REPORTS ON INVESTIGATIONS IN PROGRESS.

THE GERM-PLASM AND ITS MODIFICATION.

COMPARATIVE STUDY OF THE CHROMOSOME GROUPS IN DIPTERA.

Dr. C. W. Metz, in association with Dr. J. F. Nonidez and Mrs. Rebecca C. Lancefield, has continued his studies on the chromosomes of *Drosophila* and other Diptera. Dr. Metz reports that, owing to the peculiarities of chromosome behavior (especially paired association) in the flies and the possible bearing of these peculiarities on genetical phenomena, it has seemed desirable to make a detailed study of the maturation processes in this group. Since no one species offers the best technical conditions, and since the cytological processes seem to show differences, there is being made a comparative study of numerous species scattered through the order. A study of spermatogenesis in two species of robber flies (*Asilus*) by Metz and Nonidez has been completed, a similar study of a stratiomyid fly (*Plecticus trivitattus*) is nearly finished, and studies in other families are partially completed; studies on oögenesis in three families of Diptera are under way.

The studies in *Asilus* yielded a result of great theoretical importance. In the zygote, as is well known, each kind of chromosome is paired, one of each pair coming from the egg and one from the sperm. In a cell-generation before the ripe gametes are formed the "homologous" members of the pairs come together in what is called "synapsis." In the following cell-division the two members of each synaptic pair separate, one going to each daughter-cell, so that the ripe gamete contains only one of each homologous pair. Now Metz has found that in *Asilus* the homologous chromosomes remain closely associated throughout the entire growth-period of the first spermatocyte, with a consequent modification of the synaptic processes, due to the elimination of the leptotene and zygotene stages. True synapsis occurs in the telophase of the last spermatogonial division.

COMPARATIVE GENETICAL STUDIES ON DROSOPHILA.

The studies on oögenesis, Dr. Metz reports, although incomplete, suggest that in the female the processes may be different from those in the male, and that the difference may be responsible for the difference in genetical behavior in the two sexes (crossing-over in the female but not in the male) of *Drosophila*. This study is being extended in the hope that the question may be settled by a combination of cytological and genetical work on favorable material, as follows:

"In conjunction with the cytological studies on *Drosophila*, considerable genetical work has been carried on for the purpose of analyzing the genetical constitution of the chromosomes in different species of *Drosophila* and ascer-

taining, if possible, their genetic relationships. The failure of all attempts at hydridizing species having different chromosome numbers has led to an extension of the intensive study of the selected individual species mentioned in previous reports. The genetical analyses thus obtained are being compared with one another and with that of the well-known *Drosophila melanogaster* (*ampelophila*).

"Studies on *Drosophila virilis* (a species possessing 6 pairs of chromosomes) have resulted in the identification of 5 groups of linked genes, representing, it is believed, the 5 large pairs of chromosomes. Approximately 30 genes are represented in the 5 groups. The sex-linked group of characters in *D. virilis* contains 3 members showing such a resemblance in morphological features and genetical behavior to 3 in the sex-linked group of *Drosophila melanogaster* as to suggest very strongly that they are homologous in the two species and, consequently, that the sex-chromosomes of the two species are similar in constitution. In the non-sex-linked or autosomal groups the evidence is insufficient, as yet, to indicate whether or not similar homologies exist between other chromosomes in the two species.

"In *Drosophila willistoni* more than 40 mutant characters have been studied—mainly by Mrs. Rebecca C. Lancefield. These characters fall into three groups, corresponding to the number of large chromosomes. Particular interest attaches to *Drosophila willistoni* because of the lack of any conspicuous parallelism between its mutant characters and those of any other species thus far studied. No explanation of this fact is apparent at present, and a detailed discussion of the results may, therefore, be postponed until further evidence is secured.

"Our material of *Drosophila obscura* has been transferred to Mr. D. E. Lancefield, of Columbia University, who has undertaken extensive work on this species."

STERILITY IN MUTANT HYBRIDS OF DROSOPHILA VIRILIS.

Dr. Metz and Dr. Weinstein have discovered in *Drosophila virilis* a series of 3 allelomorphic sex-linked mutations affecting the eye:

(1) *Rugose:* Characterized somatically by a slight paling and roughening of the eye, evident in the male only, the female being entirely normal in appearance; in fertility both sexes seem to be fully equal to the wild stock.

(2) *Glazed:* This is more extreme in all respects; the eyes have a glazed appearance in both sexes, though the males are the more affected. Affected females are usually sterile. Of 150 females tested, 3 only were fertile. The males have a reduced fertility.

(3) *Wax:* This is still more extreme. The eyes of both sexes are greatly affected, resembling masses of yellow wax. The females seem to be practically or entirely sterile. The males appear to breed more poorly than do the glazed males; when rugose and glazed are crossed the hybrid females are rugose-like, but are all sterile. When rugose and wax are crossed, the hybrid females are all rugose-like but nearly all are sterile. Hybrids from "rugose," "glazed," or "wax" mated with other mutants are fertile. It appears, then, that the sterility of "glazed" and "wax" does not reappear in hybrids with more fertile mutants except their allelomorph "rugose." This sterility of certain

mutants is a matter of great importance, to the investigation of which this Station is devoting much attention, both in animals and plants.

MODIFIABILITY OF THE GERM-PLASM BY ALCOHOL.

In earlier Year Books have been outlined plans for studying the inheritance, if any, of the effects of alcohol. In making this study some rats of a litter of an inbred (and therefore probably homozygous) strain of rats were subjected to alcohol; others of the same litter were not. It was to be expected that the first generation of offspring (derived from germ-cells in the body of the alcoholized parents) would show the effects of this alcoholism; any defect would then be ascribed to a modification of those germ-cells. But if the grandchildren also are modified, that would indicate that the germ-plasm of the reproductive cells of the treated grandparents had been modified. It can not be denied that the effect might possibly be due to a modification of the cytoplasm of the germ-cells of the treated individuals; but this is, perhaps, less probable.

Maze-behavior of the grandchildren of alcoholized rats: With the cooperation of Miss Vicari and of other members of the staff, Dr. MacDowell has during the year completed the first formal report on the experiments of the hereditary effect of alcohol on rats, started in 1914. This paper has been submitted for publication in the Journal of Experimental Zoology, under the title, "Alcoholism and white rats. I: Influence of alcoholic grandparents upon maze behavior."

In this paper there are compared, with great care, various parallel series of measurements of reactions in the maze of the grandchildren of alcoholized rats and the grandchildren of non-alcoholized rats that were sibs of the alcoholized ones. A comparison was made of the time taken in learning the maze during the entire 24 trials of the original training; also, separately of the first 12 trials, of the second 12 trials, and of all but the first 3 trials. After having learned the maze, the rats rested for a period and were then again tested in the maze to find out how well they retained what they had learned. The two series were compared by giving each rat 12 trials in this retention test. The 24 original learning trials and the 12 retention-test trials were combined for a comparison. Furthermore, the daily record (of 3 trials per day) was compared for the two series.

To the above comparisons of learning and retention ability of descendants of alcoholic and non-alcoholic rats were added the following: The distance covered in running each trial; the speed, or distance per second; the different types of errors made; the number of trials before the first perfect trial, and the time spent in running perfect trials.

Dr. MacDowell reports further:

"Whenever the numbers appeared large enough to warrant the calculation of standard deviations, these have been obtained and the probable errors of the averages and of the differences between the test and control averages

have been given. The chi-square (χ^2) test has been applied to the data on time and distance, to discover how unlikely it is that such differences as are found between the test and control data are due to chance, instead of to the treatment of the grandparents. In making the averages the following groupings of rats have been used (in each of these the tests are always compared with the corresponding controls): strains separately with sexes separately; strains together with sexes separately; strains separately with sexes together; strains together with sexes together. In this way the unsettled questions of the genetic differences between strains and sexes may be eliminated. Briefly, these various groupings of the data show that the general conclusions are independent of whatever strain and sex differences may exist.

"In table 1 are given extracts from the results, with strains and sexes together. The greatest interest lies in the number of times the differences between the averages of the tests and controls exceeds the probable errors of these differences. When the quotient of the error into the difference is 3 or higher the difference may be considered statistically significant, that is, the probability is at most only 1 in 20 that such a difference will be due to chance. Plus differences indicate that the tests took more time or covered more distance than the controls. D/P.E. signifies the quotient of the difference divided by the probable error of the difference.

TABLE 1.—*Time (in seconds) and distance averages of the grandchildren of alcoholized rats (tests, 25 rats) compared with the grandchildren of the non-alcoholized grandparents (controls 25 rats) on each day of the training in the maze.*

Day.	Time elapsed in reaching center of maze.				Distance traversed in reaching center.			
	Tests.	Controls.	Difference.	D/P. E.	Tests.	Controls.	Difference.	D/P. E.
Training:								
1st.....	1862.6	1176.7	+686.0±143.3	4.79	1358.3	999.7	+358.6±73.1	4.9
2d......	334.2	203.4	+130.8± 39.3	3.33	476.3	382.7	+ 93.6±33.6	2.78
3d......	163.7	101.5	+ 62.2± 15.77	3.94	356.5	269.7	+ 6.8+27.0	3.21
4th.....	110.2	65.5	+ 44.7± 9.84	4.54	284.4	220.1	+ 64.3±15.4	4.2
5th.....	93.1	78.9	+ 14.2± 11.30	1.24	302.7	252.1	+ 50.6±23.9	2.1
6th.....	97.9	83.6	+ 14.3± 11.02	1.30	295.8	241.8	+ 54.0±19.9	2.7
7th.....	90.3	66.0	+ 24.3± 9.21	2.63	263.6	230.3	+ 33.3±19.3	1.7
8th.....	73.3	63.4	+ 9.9± 8.42	1.17	238.2	223.3	+ 14.9±19.5	0.8
Retention:								
1st.....	87.4	92.6	− 5.2± 8.50	0.61	231.9	242.2	− 10.3±14.9	0.7
2d......	58.8	55.0	+ 3.8± 8.10	0.47	217.0	185.9	+ 14.8±24.2	0.6
3d......	56.9	38.6	+ 18.3± 6.2	2.90	199.7	165.4	+ 34.3±15.7	2.2
4th.....	65.3	37.8	+ 27.5± 6.91	3.98	224.3	162.8	+ 61.5±15.8	3.9

"The time, distance, and errors criteria agree in showing the following: In all cases the averages indicate a greater capacity for learning the maze by the controls; in the majority of cases these differences are great enough to be considered statistically significant. The exceptions tend to appear in the last part of training and in the retention test. It is suspected that the maze was simple enough to be learned by all the rats, but that the alcoholism of the grandparents of the tests tended to make them slower in learning it; in the first part of the training, the differences are great enough to be significant, while in the last part many of the rats do not continue to improve and the differences in the averages are reduced, but they still lie in the same direction. However, the results subsequently obtained for the preceding (the filial) generation conflict with this explanation, since there the first days of training do not show any clear inferiority of the tests, but in the latter days the differences are statistically significant, favoring the controls.

"The speed of running (centimeters per second) does not give any clear difference between the tests and controls as to the general rate of movement. The males and females in two strains show the speed of the tests less than that of the controls, but in the third strain the speed of the tests is greater than that of the controls. None of these differences is so great that it may not reasonably be due to chance; in no case is the difference as great as three times its probable error. The conclusions to be drawn, then, are that (1) there is no general difference in the nature of the two series of rats as expressed in the rate of their movements; (2) there is a difference that retards the learning of the test rats.

"Perfect trials, or those made without wrong turns, afford a clean-cut method of comparing the tests and controls. When the number of perfect trials made in the total number of trials by each rat was considered, the following results were found (table 2):

TABLE 2.—*Numbers of perfect trials.*

	Tests.	Controls.	Differences.	D/P. E.
Training	1.48	2.76	+1.28±0.40	3.07
Retention	2.58	4.20	+1.62±0.40	4.05

"It is plain that the tests made fewer perfect trials in the given number and that the difference is great enough to be significant. The second use of the perfect trials is to compare the number of trials before the first perfect one was made. The averages obtained were: Tests, 19.48; controls, 13.82; difference, 5.66±1.66; D/P.E., 3.41.

"Here again the tests are inferior, taking more trials before learning to make the first perfect one. In this case also the difference is too great to be due to chance alone. The third criterion based on perfect trials is the time spent in running them; the final averages (in secs.) are as follows: Tests, 8.48; controls, 7.52; difference, −0.95±0.25; D/P.E., 3.84.

"Although there does not seem to be a general difference in the speed of the tests and controls, there does appear to be a significant difference in the time that the two sets required in running their perfect trials, the controls going faster.

"We believe that the above points show that the tests and controls differ as groups in their behavior in the maze. From the standpoint of learning their way to the center and going there for food, the tests are less successful than the controls. The alcoholic treatment of the grandparents is the only basis upon which the rats have been divided into the groups of tests and controls; therefore the alcoholic treatment of the grandparents seems to be responsible for the inferiority of the tests in running the maze."

"*Maze-behavior of the children of alcoholized rats.*—Since the extensive study of the generation described above has shown that the various criteria for the comparison of the tests and controls give closely similar results, it has seemed necessary to use only part of the available criteria for the other rats. Therefore, for the other generations we decided to employ only time and the three criteria dependent on perfect trials, omitting distance, speed, and errors.

"During the summer Miss Charlotte Gilman has summarized the data on the maze-behavior of the children of the alcoholized rats. The parents of the rats considered above were of this generation. Although these results are still subject to certain further checkings, they are presented at this time for comparison with the other generation. It may be stated at once that the com-

parison of the tests and controls in this generation gives, as a whole, the same sort of results as given by the rats in the next generation, namely, the test rats, on the average, do worse than the controls. But instead of being greater, the difference between the tests and controls (although one generation nearer to the actual alcohol) is less marked.

"There are about 100 rats in this generation, from four strains. Three of these strains show a clear preponderance of averages favoring the controls when the trials on each day of training are taken separately; the fourth strain does not show any difference at all between the two groups. The averages for time obtained, when all strains are put together, are shown in table 3; the differences on each day are plus (the tests taking more time), with the single

TABLE 3.—*Averages of time elapsed in reaching center of maze per day of 48 children (tests) of alcoholic parents compared with 45 controls on each day of training on the maze.*

Day.	Tests.	Controls.	Difference.	D/P. E.
Training:				
1st	1906.5	1901.5	+5.9±140.5	0.03
2d	429.6	399.4	+30.2± 58.1	0.52
3d	145.7	152.3	− 6.6± 24.0	0.27
4th	141.4	76.5	+64.9± 17.7	3.66
5th	90.4	61.7	+28.7± 7.4	3.88
6th	64.8	53.1	+11.7± 5.1	2.29
7th	55.9	46.8	+ 9.1± 3.3	2.76
8th	52.6	40.9	+11.7± 3.6	3.25
Memory:				
1st	125.5	113.2	+12.3± 16.5	0.74
2d	66.5	47.7	+18.8± 6.0	3.13
3d	47.3	37.6	+ 9.7± 4.1	1.62
4th	49.5	40.7	+ 8.8± 3.4	2.59

exception of the third day. However, on none of the first three days are the differences great enough to have any significance. For the most part, the differences on the other days do show that the tests are significantly slower in running the maze than are the controls. The criterion of perfect trials gives similar results. The controls made more perfect trials; they required fewer trials before making the first one; and they spent less time in running them.

TABLE 4.—*Comparison of children in respect to perfect trials.*

	Tests.	Controls.	Difference.	D/P. E.
Perfect trials	4.00	7.08	+3.08±0.56	5.50
Trials before first perfect trial	19.40	15.80	+3.60±1.39	2.59
Time spent on perfect trials	7.7	7.1	+0.60±0.17	3.52

It is too soon to make final comparisons between the generations, but the results so far seem to show that two of the three strains that are represented in both generations bear the same relative positions in each generation. Strain C is a fast one in both generations; strain L a slower one; strain A, however, is different in the two generations, being slower in the later generation. This difference in strain A may very possibly be associated with the appearance of a sort of inherited hydrocephalous (*pig-headed*) condition in the later generation.

"A more striking result of the comparison of the two generations is that the differences between the tests and controls are greater in the generation farther away from the alcohol. This is especially the case in the first three days of the training, where the differences are great in the second generation, but in the first generation are practically non-existent. In the later days the actual differences between the tests and controls in the two generations are not very unlike. However, when these differences in the later days are considered, it appears that they are not significant in the second generation, while in the first, due in part to the larger numbers, they are fully significant. Thus there are significant differences in the first part of the training for one generation and in the second part of the training for the other generation, although in both generations all the significant differences are in favor of the controls."

The above indicates that the effect of alcohol was certainly not purely somatic, due to alcohol in the blood of the mother entering the vessels of the fetus, for if this were the case, the grandchildren should show *less* rather than *more* difference between the tests and controls. There is some effect handed down; whether it originated in the germ-cells of the embryos of the offspring of the treated mothers, or in the germ-cells of the parents themselves, can not be decided from the evidence at hand. The only data on this point appear to show that the germ-cells of the fathers alone were not sufficiently modified to affect the offspring. A small group of 5 rats, whose father was treated and whose mother was normal, compared with 7 normals from the same pair of grandparents, do not show any effect of the alcohol treatment; on some days the averages of the test rats are higher, on some days the averages of the control rats are higher, with no preponderance either way. If this result has any significance it may be due to two things: either that the amount of alcohol taken by one parent was not enough to modify the offspring, or else the susceptible age is while the individual is *in utero*. Unfortunately, no further generation was raised from these rats. It appears to be entirely possible that the difference in first days of training in the two generations studied may be due to two different effects of the alcohol treatment; there may be working both (1) a direct somatic effect that does not modify the first part of training, but which tends to make the rats move more slowly in the last part, after the habit is well learned, as well as (2) a germinal effect that does not make itself manifest till the next generation, and then modifies the nervous system rather than the muscular mechanism and hinders the learning process that goes on in the early trials.

"*Maze-behavior of rats from parents and grandparents treated with alcohol.*—Miss Vicari has made summaries of the training records of a set of rats that came after two alcoholized generations. Of these there were 9 tests and 9 controls. When the time data were averaged for each day of training separately, the differences in every case in the original training were plus, that is, the tests took more time. In the trials of the retention test given a month later, the controls took more time on the first and third days; the tests took more time on the second and fourth days. Since the number of rats is so

small, the probable errors are naturally very large; indeed the differences, large as they seem, are more than three times their probable errors on only a few days. These days are at the end of the training period (sixth, seventh, and eighth days) and the last (fourth) day of the retention test. The differences between the averages on the earlier days are much greater, but the variability at this time is so much greater that the significance is much reduced (see table 5).

"The criterion of perfect trials fully supports the findings of the time data. The tests made fewer perfect trials, required more trials before making a perfect trial, and the average of the time spent by the tests in running perfect trials is greater than the average for the controls, yet this difference is not great enough to be significant. Plus signs indicate that the tests took more time.

TABLE 5.—*Averages per day of time elapsed in reaching center of maze by 9 rats (tests) whose parents and grandparents were alcoholized, compared with 9 controls.*

	Tests.	Controls.	Difference.	D/P. E.
Perfect trials	1.16	7.00	+ 5.84 ± 0.98	5.96
Trials before first perfect trial	33.44	17.0	+ 16.44 ± 2.03	8.10
Time spent on perfect trials	8.97	7.74	+ 1.23 ± 1.06	1.16
Training:				
1st day	2000.53	1977.36	+ 23.17 ± 301.50	0.08
2d day	948.64	827.25	+121.39 ± 271.20	0.45
3d day	591.14	367.21	+223.93 ± 148.80	1.50
4th day	449.80	215.97	+233.83 ± 87.16	2.41
5th day	267.82	128.60	+139.22 ± 69.13	2.01
6th day	166.27*	68.20*	+ 98.07 ± 25.91	3.78
7th day	156.04	78.88	+ 77.16 ± 24.44	3.16
8th day	139.84	62.44	+ 77.40 ± 25.77	3.00
Memory:				
1st day	121.13	105.94	+ 15.19 ± 25.31	0.60
2d day	71.53	47.74	+ 13.28 ± 16.56	0.80
3d day	34.16	39.11	+ 4.05 ± 4.93	0.82
4th day	130.53	35.22	+ 95.31 ± 16.97	5.62

*Excluding one abnormal rat.

"If the hypothesis suggested as an explanation of the different results given by the two generations compared above is at all correct, one would expect to find in this case that both the first and later parts of the training gave real differences, since there would be opportunity for both sorts of effect to be manifest—the immediate somatic effect from the mother, and the germinal effect from the grandparents upon the germ-cells of the parents. And the table shows that the differences in the first days are greater than those differences shown above (table 2) in the early days of the training of the first generation, but the significance of the differences resembles the findings in this first generation rather than those in the following generation, namely, the last part of the training gives significant differences and the first part does not. With such a small number of animals this result has no decisive significance, but as far as it indicates anything it goes in the direction that the suggested hypothesis demands."

"*Results of the multiple choice training.*—The apparatus used in this training consisted of a series of nine compartments, each of which had front and back doors, operated at a distance by the observer; different sets of these front doors were opened at different trials and the rat was given its reward of

food when it entered the correct compartment (at the extreme right or left, as the problem might be—the 'end-compartment'). The steps in the training were these: Preliminary training, when the regular series of doors was opened in successive trials, but the rat was fed upon entering any compartment (2 days, 20 trials); right-hand problem, when the rat was fed only when it entered the open compartment at the extreme right (10 days, 100 trials); the same problem with a different series of doors open (2 days, 20 trials); left-hand problem, when food could be obtained only upon entering the open compartment at the extreme left (10 days, 100 trials); same problem with a different series of doors open (2 days, 20 trials); after a month, the same problem, with the same series of doors open as in the last step, to test retention (4 days 40 trials). Previously (Year Book 1919, 126) only the numbers of correct first choices and the number of wrong choices for the different parts of training were summarized, involving no comparison with the preliminary training, and no comparison was made of the different days in the same step of training to show the progress of learning. For the consideration of the progress of learning the trials have been grouped by twenties; that is, two days are taken at a time. The end-compartments seem to be especially attractive, irrespective of training, since about 70 per cent of the first choices are end-compartments through all the training, although only 57 per cent of the open compartments are end-compartments. The new summaries are based on the numbers of left end-compartments, and the numbers of right end-compartments that were chosen first in every 20 trials of the whole training; besides these, there have been studied the numbers of wrong choices, including end-compartments in the same sets of trials. There were 21 test rats used and also 21 controls.

"Figure 1 shows the percentage of the trials on which right and left end-compartments were respectively chosen first, for each of the sets of 20 trials in the whole training. The percentage for the test rats is shown by the broken lines, for the control rats by the solid lines. Trials on which the right end-compartment was chosen first are indicated by the heavy lines (both broken and solid) and trials on which the left end-compartment was chosen first are shown by the light lines.

"The right-hand first choices (heavy lines in figure 1) will first be considered. Both the tests and controls increased the percentage of right end-compartments in the right-hand problem. For the 5 points in the curve showing the regular right-hand training the tests have fewer right-hand choices, but when the different series of open compartments was given on the eleventh and twelfth days, the tests made more right-hand first choices than the controls. The general superiority of the control percentages disappears when it is observed that the tests started out in their preliminary training with fewer right-hand choices than the controls. If the slant of the curves is compared, it appears that the tests made more rapid and greater progress. On the other hand, it may not rightly be claimed that the tests were actually better than the controls, since the higher initial right-hand tendency of the controls may have in itself limited the opportunity for rapid improvement. The highest proportion of correct choices reached during the 120 trials of this problem is little over half of the trials. In the left-hand problem the number of right-hand first choices is immediately reduced in the first 20 trials. The tests and controls are both lower than in their preliminary trials. In the following sets of 20 trials there is no further reduction in the percentage of right-hand choices; the controls remain about the same, but the tests chose more right-hand doors than the controls, although the initial tendency of the tests was to choose fewer right-hand doors.

"The left-hand first choices (light lines in figure 1) will be considered. In the right-hand problem the tests and controls started with about equal left-end choices, and reduced this number at about the same rate. In the first 20 trials of the left-hand problem, when the number of right-hand end-compartments chosen first was suddenly reduced, the number of left-hand end-compartments chosen first was suddenly increased. But after this original increase, instead of showing still further improvement, the following set of 20 trials actually lowered the proportion of left-hand first choices; that is, the continued training seems to have the opposite from the expected effect. The tests (broken line) made fewer left-hand choices than the controls, but the same tendency to go against the direction of the training is obvious in both sets of rats.

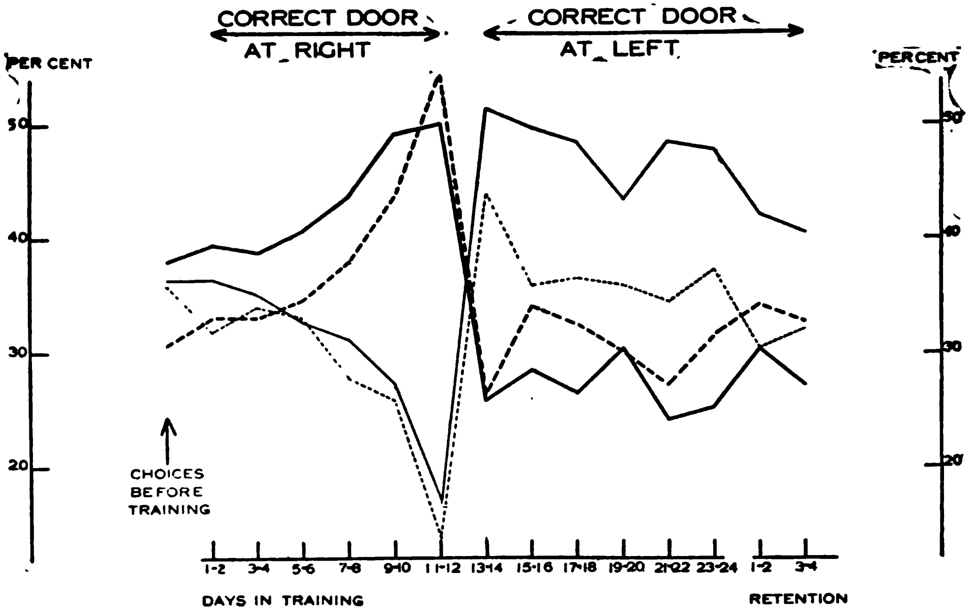

FIG. 1.—Showing the percentage of right-hand and left-hand end-compartments that were chosen first in each successive group of twenty trials per rat. The heavy lines show right-hand end-compartments chosen first, the light lines show left-hand compartments chosen first; solid lines are the controls, broken lines the tests. After the twelfth day of training the correct door was made the one on the left end, instead of the one on the right end.

"The retention trials show the tests making about as many right-hand and left-hand choices as in their preliminary trials, although the number of right-hand choices was larger in spite of the 120 trials immediately preceding, when food was given only after a left-hand compartment was chosen. The controls, on the other hand, show very plainly the retention of the tendency to go to the left end-compartment more frequently than the right end-compartment.

"When the curves like the above were drawn for each rat separately, 5 controls and 8 tests were found that did not seem to learn at all. If these rats are omitted from the summaries, the curves present the same general situations, but an exception appears in that the tests in the left-hand problem make fewer right-hand choices than the controls, instead of more, and there is less difference in this problem between the numbers of left doors chosen by the tests and controls. In other words, the elimination of these rats reduces

whatever differences previously existed between the tests and controls. More test rats failed to show signs of learning, but those that did tend to profit by experience appeared to have no handicap as compared with the controls.

"The curves for the third criterion, the numbers of wrong choices made, offer the following observations: The test and the control rats continuously reduced the numbers of wrong choices in the right-hand problem, but the controls made fewer wrong choices. Considering the stronger right-hand tendency with which the controls started out, this superiority can not be held to prove greater ability in learning or in adaptability. The rate of elimination of wrong compartments is much the same for the tests and controls.

"The tests and controls both made more errors in the first 20 trials of the left-hand training than they did in the beginning of the first problem; this is evidence that there was real learning in the first problem which interfered with the learning of the opposite problem. The second set of 20 trials in the left-hand problem shows an abrupt reduction in the number of errors, but in the following sets of trials errors are eliminated much more slowly. During this time the controls have made more progress than the tests. In this problem the fewer errors made by the controls can not be explained by their original tendency, nor can it be due to any differential effect of the right-hand training, since both tests and controls were doing about the same at the end of that training.

"Although the numbers of right and left hand end-compartments that were chosen first in the left-hand problem do not indicate any improvement after the first set of 20 trials, the number of wrong choices does seem to be reduced. There are fewer correct choices, but also fewer wrong choices. This is mainly due to the elimination of repeated choices of the same door that had been a correct door in the right-hand problem.

"For the general failure of the training in the second problem, there does not appear to be any obvious explanation. Learning of this type is possible; it is demonstrated in the right-hand problem. The failure is not due to the chance effect of combining rats which individually show very different results, for only 4 rats showed anything that might be considered signs of learning the left-hand problem.

"The observations just made may be summarized as follows: Considering the end-compartments that were chosen first, it appeared that (1) both tests and controls increased the numbers of right-hand choices and decreased the numbers of left-hand choices when food was given only in the right end-compartment, whichever one that happened to be; (2) that both tests and controls reversed the preponderance of their choices from right end-doors to left end-doors in the first 20 trials after food was given only in the left end-compartment; but after the first 20 trials there was no further improvement in the direction of training, but rather a tendency for the numbers of left-hand choices to fall off and the numbers of right-hand choices to remain the same; (3) that in the first problem the test may have a little advantage, as far as there is any difference at all; in the second problem the controls appear to show a greater degree of adaptability. Comparing the preliminary training with the retention tests, the controls appear to have been more lastingly modified than the tests by the training; but when certain rats that did not appear to show any signs of learning at all were eliminated (5 controls and 8 tests), the advantage in favor of the controls in their greater adaptability in the left-hand problem no longer is found.

"There remains one valuable source of information that has hardly been touched, namely, the study of the methods employed by individual rats in meeting the situations presented, quite apart from their success as tested by

the numbers of doors of different kinds that they entered. The data, as tabulated, entirely obscure these reaction tendencies, yet these would give a different and possibly fairer test of the rats than is afforded by their relation to an arbitrarily established standard. The graphic records of each individual trial provide this information; from the record sheets it will be possible to classify the successful types of reactions on an absolute basis; how consistently the different types of reaction were shown; how sensitive the animal to extraneous circumstances, to the operation of the apparatus; thus, a study of the general motor tendencies and many other exceedingly interesting and important side-lights will be afforded.

"That the maze and the multiple-choice apparatus do not give the same results when the tests and controls are compared does not weaken the significance of the conclusions in either case. The problems are of a different nature and require different mental processes for their solution; the rats solved the one with ease, the other was not solved in the number of trials allowed. Longer training would have given greater success and probably mastery of at least one of the multiple-choice problems. It is entirely possible that the final perfecting of the solution would bring out differences between the tests and controls, however much alike their rate of learning in the beginning. On the other hand, if the performance in the early part of the learning process should be a true sample of the whole process, it is equally simple to suppose that the alcohol may have modified the nervous mechanism involved in learning the maze and have had no influence at all upon the processes that are involved in the solution of the multiple-choice problem. So the conclusion stands that the maze brings out differences between the tests and controls, and the multiple-choice apparatus, as far as the training went, did not bring out these or other differences."

SIGNIFICANCE AND CONTROL OF SEX.

COMPARATIVE METABOLISM OF SEXES IN PIGEONS.

Dr. Riddle has extended his studies on the metabolic differences between the eggs that give rise to the two sexes to a study of the differences in the metabolism of male and female embryos. He found it difficult to devise a satisfactory method of measuring these differences but finally adopted the following: He undertook to subject, during an entire year, all, or practically all, of the embryos produced by the ring-doves and common pigeons of our collection to reduced and to increased concentrations of oxygen, or to expose them to protracted periods of cold, and to observe the relation of sex to survival under these conditions.

Theoretically, if female embryos have a lower metabolism than male, the female embryos should withstand diminished pressures of oxygen better than male embryos. Similarly, since it had been earlier learned that high pressures of oxygen result in the death of some embryos, the male embryos should be somewhat better able than female embryos to withstand an increased concentration of oxygen. Again, if males have a higher metabolism than females, the reduced metabolism induced by cooling should prove more harmful to the male embryos.

Embryos aged 3 minutes (after laying) to 12 days were used; and most frequently the age was between 1 hour and 4 days. Increased

concentrations of oxygen varying from 26.8 per cent to 96.6 per cent and decreased concentrations varying from 18.3 per cent to 0.15 per cent have been used. The time during which embryos were subjected to the altered pressures of oxygen has varied from 1 to 5 days. For 0.15 per cent O_2 the time was 15 minutes to 8 hours.

During treatment the embryos were kept in a sealed chamber (a modified desiccator) into which prepared washed gas of known concentration was continually fed and then led away. Two to five analyses were made daily of gas samples drawn from the chamber. Before and after treatment in the chamber (kept at 103.0° F. in a Freas oven) the embryos were incubated by doves, either by the parents or by generic hybrid doves maintained for this purpose.

The age of the embryo has been found the most important factor in survival under alteration of the gaseous environment. Older embryos are most affected by reduced pressures of O_2; younger embryos most affected by increased pressures of O_2. It is probable, but not now certain, that the adequacy of thickness of the shell is also a factor in such survival. Probably the egg-shell normally acts as a buffer against the oxygen of the air. This adequacy of the shell has been painstakingly measured by Dr. Riddle in all of the treated embryos. A small number of embryos has been simultaneously treated with increased pressures of oxygen and carbon dioxide. From 8.0 per cent to 46.0 per cent of CO_2 have been employed. In the embryo these two substances doubtless have in part antagonistic effects. Table 4 presents the chief data obtained concerning sex. It will be understood that the sex of many embryos which were killed, and even of some which survived treatment but died later, could not be ascertained. The results thus far obtained, with the year three-fourths completed, indicate that sex is also a factor in survival.

TABLE 6.—*Comparison of effect of variations of percentage of oxygen in the atmosphere on male and female embyro pigeons.*

Nature of treatment.	No. of embryos treated.	Embryos.		Sexes.		
		Killed.	Survived treatment.	Killed.	Survived.	Total.
				♂ : ♀	♂ : ♀	♂ : ♀
Increased O_2.............	596	247	345	8 : 11	173 : 121	181 : 132
Decreased O_2.............	536	264	258	35 : 19	100 : 127	135 : 146
Increased O_2+CO_2.......	146	109	35	1 : 3	17 : 13	18 : 16
Cooling..................	297	155	139	30 : 18	62 : 62	92 : 80

The tabulated data show that fewer males than females were killed by increased pressures of O_2, and that more males survived this treatment. More males were killed by decreased pressures of O_2, and

fewer survived this treatment; also, when subjected to cooling, more males were killed and fewer (in proportion to total) survived. In all these respects Dr. Riddle is convinced that the metabolic theory of sex is supported. The pigeons, therefore, have now supplied cogent evidence of fundamental, metabolic sexual difference in their germinal, embryonic, and adult stages.

MODIFICATION OF THE SEX-RATIO IN MAN.

The standard sex-ratio may be considered to be 100 males to 100 females. In some species where the ratio deviates far from 100, a special explanation is demanded and has sometimes been received. The sex-ratio in man is usually over 100—not far from 105—and this deviation is doubtless due either to the fact that male-producing sperm have a better chance of fertilizing the egg than female-producing sperm, or else that the male embryo (zygote) is more viable, on the average, than the female embryo (zygote). Dr. Little is paying special attention to the human sex-ratio, and his work was reported on in the Year Book for 1919 (pp. 135–137). It was there pointed out that the sex-ratio is greater when the parents belong to different European races than when they belong to the same, as 122 is to 106. It now appears that when both parents are whites born in the United States the ratio is high (118), which we might expect in view of the hybrid nature of our white population. Studies on the sex-ratio in the colored population yield some new and unexpected facts. The sex-ratio of the offspring of colored parents born in the United States is exceptionally low (96). Of offspring of colored parents, born in the British West Indies, and probably *less* hybrid than the progeny of colored persons born in the United States, the sex-ratio is 108. If we may regard the West Indians as less hybrid, then on the basis of the findings in Europeans we should expect a smaller ratio than in offspring of colored Americans. While in white primapara the sex-ratio is higher in first births than in offspring of subsequent births as 115.5 ± 1.5 is to 97.3 ± 1.2, in the colored population the sex-ratio is the lower in first births as 103.6 ± 2.8 is to 112.0 ± 2.8.

SEX-LINKED LETHAL FACTORS IN MICE.

One important cause of disturbance of the sex-ratio is the presence of some lethal factor in, or the absence of some vital factor from, the sex-chromosome. Dr. Little has found the sex-ratio of inbred, non-waltzing mice to be 103.1 ± 2.8, giving the usual slight excess of males. The sex-ratio of litters from a closely inbred race of Japanese waltzing mice is 53.2 ± 5.7. The difference between the two sex-ratios is 7.9 times its probable error, so it is certainly significant. Reciprocal crosses of animals from this particular strain of inbred waltzing mice with non-waltzing races give extremely interesting and distinct results.

Thus Japanese waltzing females crossed with non-waltzing males give a sex-ratio of 44.0 ± 7.4, while Japanese waltzing males crossed with non-waltzing females give a sex-ratio of 118.2 ± 3.8. The latter result is commonly obtained in hybrid combinations, but the former represents a departure from the normal type requiring explanation.

Dr. Little advances the following hypothesis as that which best fits all of the observed experimental facts. In some of the females of the inbred Japanese waltzing race there is a recessive lethal factor which is sex-linked. Such females would transmit the lethal factor to one-half their male progeny. Males of this sort, having the lethal in an unbalanced condition, would not survive, thus producing a sex-ratio of 1 male to 2 females or 50.0 in the progeny of such females. All surviving males would, by hypothesis, lack the lethal, and therefore could not transmit any peculiarity of the sex-ratio to their progeny. The result of the cross (Japanese waltzing male by non-waltzing female) is thus explained. One-half of the female progeny of the lethal-bearing females should theoretically be homozygous normals and one-half should transmit the lethal. In more advanced hybrid generations descended through Japanese waltzing females an excess of females should thus be produced. The exact ratio would depend upon the proportion of lethal-bearing to homozygous normal females in the population. Actually such an excess of females has been obtained. The sex-ratio of advanced hybrid progeny descended through the Japanese waltzing female line is 78.7 ± 2.9.

The size of litter also affords supporting evidence for the presence of a lethal. Frequency polygons for litter-size in Japanese waltzing and in non-waltzing females have been compared by a χ^2 test. The 58 litters from Japanese waltzing females average 3.38 young per litter, while those from non-waltzing females (100) average 5.93. The odds are greater than 1 in 100,000 against the distribution curves being the same. Since Japanese waltzing females should be of two general types, (*a*) those producing small litters, due to the lethal, and (*b*) those producing larger litters when free from the lethals, the result falls in line with the sex-ratio evidence.

It seems clear, therefore, that certain females of the closely inbred Japanese waltzing-mouse race are transmitting a recessive, sex-linked, lethal factor. This is, it is believed, the first case of a sex-linked lethal in mammals and the first case of sex-linkage in rodents.

DIFFERENCES IN RESISTANCE OF SPERM OF DIFFERENT SPECIES TO ACID SOLUTIONS OF VARIOUS STRENGTHS, IN RELATION TO THE SEX-RATIO.

In the annual report of the Institution for 1919 the hypothesis was stated that certain peculiarities in the sex-ratio might be due to variations in the quality of the internal secretions of the female reproductive

tract at different times. Also, it was suggested that these secretions may act in a different degree upon the male-forming and upon the female-forming sperm. The female-forming sperm with its larger amount of functional chromatin offers more opportunity to produce physiological incompatibilities and therefore to be eliminated than the smaller male-forming sperm.

It has long been known that the hyperacidity of the vaginal secretions is a powerful factor in producing sterility. Evidence also exists that before pregnancy the os of the uterus is so small that there is little, if any, opportunity for the slightly alkaline secretions of the uterus to mingle with and neutralize the acid vaginal secretions. After the first birth the os is often enlarged or torn and more chance for admixture of the secretions exists. Since acidity is known to be harmful to sperm, and since the selective and eliminating power of the vaginal secretions might, by alterations of its acidity, be changed, it seemed of interest to determine what was the behavior of sperm in various concentrations of acid. For this purpose glacial acetic acid was chosen. The work was planned and carried out by Dr. Little with the assistance of Miss Marion Gibbons.

The results are tabulated below. Control drops were used on the same microscope slides with the treated drops. Each test was repeated three times. The sperm was kept in warm Ringer's solution. The different reactions of the various sperms are striking.

TABLE 7.—*Reactions of spermatozoa of various mammals to acid solutions.*

Ratio of glacial acetic acid to water.	Type of sperm used.	Results.
1 : 6,400	Mouse....	Kills all sperm immediately.
1 : 11,200	Mouse....	Greater part of sperm move normally; few stop.
1 : 12,800	Mouse....	Sperm unaffected.
1 : 9,600	Rabbit....	Kills all sperm immediately.
1 : 12,000	Rabbit....	Few sperm stop; greater part are unaffected.
1 : 12,800	Rabbit....	Apparently all sperm live.
1 : 24,000	Rat.......	All sperm stop immediately.
1 : 66,000	Rat.......	Over 50 per cent of the sperm stop.
1 : 70,000	Rat.......	Very few sperm stop; greater part move normally.
1 : 40,000	Dog......	All stop immediately.
1 : 210,000	Dog......	Slow down greatly and eventually most stop.
1 : 300,000	Dog......	Some stop, but the majority go on normally.

Since the mouse and rat sperm-cells are easily distinguishable in size, a mixture of the two was made and treated with solutions of acetic acid as follows:

TABLE 8.—*Reactions of mixtures of mouse and rat sperm-cells to acid solutions.*

Ratio of glacial acetic acid to water.	Type of sperm used.	Results.
1:11,200	Mixture of mouse and rat	All motion of rat sperm stops; very few mouse sperm stop; greater part move normally.
1:12,800	.....Do.........	All rat sperm stop immediately; mouse sperm unaffected.
1:68,000	.....Do.........	Very few of rat sperm stop; greater part of rat sperm and *all* mouse sperm move normally.

From the above data it may be concluded that there is differential mortality in the sperm-cells of different species when subjected to weak solutions of acetic acid.

SELECTION OF SEX INTERGRADES IN DAPHNIA.

As noted in last year's report, Dr. Banta has undertaken to increase or decrease the amount of a sex-intergrade condition that he discovered in the water-flea, *Daphnia*, by means of selection based on somatic differences. At that time it was thought that it could be concluded that strains like No. I, selected for increased intergradeness, would probably not become more intergrade; but strains like Nos. III and V, selected to produce normal females, could tend to become so. All mothers received identical treatment so far as practicable—culture water was taken from the same jar and the temperature was maintained in each at the same level. By means of a somewhat arbitrary scale, running from 0 to 80, the degree of intergradeness may be expressed quantitatively. It is to be recalled that all strains descended parthenogenetically from the same progenitor.

The procedure and the results with intergrade strains I and III were as follows: Strain I was maintained as a "high" intergrade strain. Its level fluctuated from 10 to 33, averaging about 22 on the scale of intergradeness. Strain III was selected as a "low" strain. Selection was effective in the seventh generation, the level falling to about 3. After five further generations of selection the level fell to about 1. In the nineteenth generation there was an abrupt rise in this low strain to 20, after which, during four generations of selection, it fell to 0, producing none or very few slight intergrades for the next five generations. Later, it again went to somewhat higher levels. However, in spite of all the fluctuations in both the high (I) and the low (III) strains after the sixth generation a pronounced divergence between the two strains was maintained (fig. 2).

In the nineteenth generation a return selection was begun in the low strain (III) to produce a high strain. Unfortunately this was begun when Strain III was at a rather high level, but the result was the same in Strain V, another low strain, which was at a low level when return

selection was begun. The effect was pronounced. In two generations the new high strain (X) attained even a higher level than the original high strain and maintained a level as high as that for Strain I.

In the twenty-ninth generation a low selection was begun in Strain I. The result was the immediate production of a low strain (XII, see fig. 2). At the same time a low selection was begun in Strain X, the high strain, which was itself a return selection from Strain III. A low strain (XIV) was obtained in the second generation of selection. These selection experiments are represented diagrammatically in the figure, the abscissas representing generations of descent and the ordinates degrees of intergradeness.

Seven other intergrade strains of *Daphnia longispina* used in similar selection experiments gave similar results, so that one seems warranted in concluding that in this sex-intergrade stock selection and return selection are equally effective and that a strain may be raised or lowered in the scale of intergradeness at will by means of "selection."

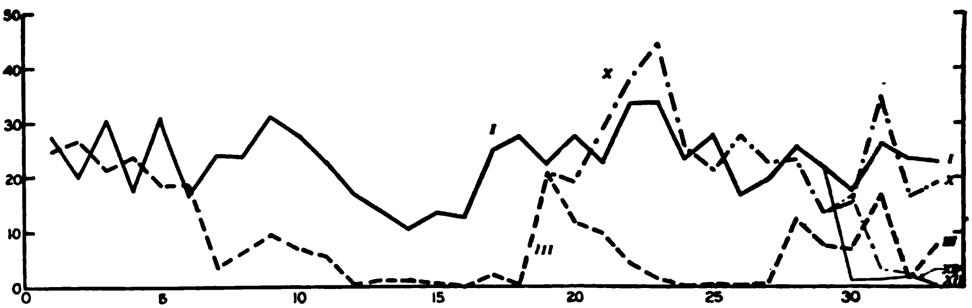

Fig. 2.—Curves showing diagrammatically some of the selection experiments with sex intergrade strains of *Daphnia longispina*—Strains I, III, X, XII, and XIV. The abscissas represent generations of selection, the ordinates degrees of intergradedness. Roman numerals indicate the strain numbers while the courses of the curves indicate which were selected as high and which as low strains.

The interpretation of the results of "selection" in *Entomostraca* is not entirely clear, since there are numerous elements of the problem that are unknown. To these principles we hold fast: Selection in a proper sense selects only what is given; it does not create. Also, any inherited consequences of the selection are carried in the constitution of the gametes, either chromosomes or cytoplasm. If, then, "through selection," a parthenogenetic race has been genetically modified, it is because genetic idiosyncrasies in the desired direction have been afforded. If a rapid change has been possible through selection it is because individuals showing somatic variations carry corresponding determiners for such in their germ-cells. Thus, in making selection of visible, somatic hereditary peculiarities we are, at the same time, selecting corresponding, but invisible, gametic determiners for such hereditary peculiarities.

Just what the nature of the hereditary change in the gametes is, that the selector takes advantage of in his successful selections, is uncertain.

It may be a cytological modification, but in the great majority of cases it is chromosomal. It has been urged that, when chromosomal, it may be due to a change in the nature of a gene without a change in its identity. But a change in a gene is, for the geneticist, a new gene, whether it occupies the place of a pre-existing gene or not. It troubles some experimentalists that, through selection, a change in the race can be so soon effective; but the change had already occurred before they began their effective selection; they were merely working with a germinal change that had occurred before the phenotypic change which they were "selecting." In a species or biotype that is invariable we may be surprised if we make progress in a given direction; but in a biotype that is already showing mutations we may expect further mutations in every generation. Of course, size of the phenotypic change induced in the mutation is never to the point; sometimes two or more changes in genes induce no visible, phenotypic change.

SEX IN MUCORS.

Work on the sexuality of the mucors has been continued by Dr. Blakeslee. He has accumulated a considerable body of new data on the results of testing the sexual interactions of diœcious species. In 15 different species, representing 9 different genera, over 1,600 individual races have been tested in pairs for the production of zygospores. Nearly 10,000 combinations have thus been made, with the result that each race tested has been shown by the presence or absence of zygospore formation to belong to the plus (+) or minus (−) sex or to show no sexual reaction in any combination. No sex intergrades have been discovered. Different races have different strengths of sexual vigor, as shown by the intensities of zygospore formation. The "neutral" races, which have not as yet shown zygospores in any combination, may be the low extremes of a graded series into which the sexually active races can be arranged, based on the abundance of zygospores which they form in different combinations. We have just completed a series of tests of sexual reactions between races of different species and have thus made a total of over 2,000 combinations. "Imperfect hybridization" has taken place only when the races grown in contact belonged to the opposite sexes, minus (−) and plus (+). The "imperfect hybridization" work confirms the conclusion drawn from the tests between races of the same species, viz, that a stricter sexual dimorphism is present in the diœcious mucors than in diœcious species of higher plants. It is suggested that this difference may be connected with the fact that in the mucors we are dealing with gametophytes, while in higher plants we are dealing with sporophytes.

Dr. Blakeslee has pointed out, in his recent vice-presidential address before Section G of the American Association for the Advancement of Science, that as a criterion of sex the relative size of the two uniting gametes (the larger being called female and the smaller male) does not

lay hold of the fundamental differences between the two sexes. He concludes that the "plus" races of mucors may be homologous in some cases with what has been called male and in others with what has been called female.

INHERITANCE OF GERMINAL PECULIARITIES.

FLOWERING PLANTS.

Portulaca.—In the breeding of this species Dr. Blakeslee has obtained additional data as to the factors responsible for its color types. One of the most interesting properties of the portulacas is their ability to undergo vegetative mutations. Dr. Blakeslee has a paper in press describing the dominant vegetative mutations to normal habit of growth that occur in recessive dwarfs, previously described in the Year Book. Color characters also arise as dominant vegetative mutations. Last year, in a line which for several generations had borne white flowers and which had never shown red pigment in any of its parts, a single plant was discovered one branch of which was slightly red and bore white flowers with pink filaments. The two types of flowers were selfed individually. Seeds from the normal white flowers have this year given uniform pedigrees with white flowers, while seeds from the flowers with pink stamens have given pedigrees with yellows and whites in a 3:1 ratio. The pink-stamened white flowers therefore bred like a heterozygous yellow.

In another white-flowered pedigree, a plant was found which, in addition to white flowers, bore some purple flowers and some flowers the petals of which showed a centrally located "fan" of pale purple. Seeds from the white flowers of this plant have bred like whites of this line; seeds from the purple flowers have segregated for purple and white, while seeds from the "fans" have bred like the heterozygous purples.

In a third line there have been found certain purple flowers breeding like whites. The genetics of these three cases becomes intelligible, Dr. Blakeslee concludes, if we consider them examples of periclinal chimeras. Pigment in the petals is located almost exclusively in the epidermal layers, while it is the subepidermal layers which take part in the formation of the germinal tissue. In the first example, a white epidermis covered a subepidermal tissue which carried factors for yellow. In the second example, in which the purple flowers and white flowers with pale purple "fans" bred alike, the "fan" flowers had a white epidermis with a subepidermal layer carrying the factors for purple, and therefore bred like a purple. In the third example, where a purple flower bred like a white, the epidermal layer alone apparently carried pigment and the subepidermal layers were devoid of factors for purple pigmentation. The histological evidence so far obtained is in accord with this conception. "Fan" flowers are devoid of purple in the epidermis, but contain purple pigment in the cells sheathing the bundles. Moreover, some purple flowers have been found with purple

in both epidermal and subepidermal layers, while in other purples the color seems confined to the epidermis. The occurrence of sectorial and periclinal chimeras and mutative stripes and spotting render the portulacas a favorable species for the study of vegetative mutations.

Datura.—In the jimson-weed, work has been brought to a close on the graft-infectious disease "quercina," which causes profound morphological changes in the plants affected; and the results of the investigations are embodied in a paper now in press. It is suggested that the non-Mendelian behavior of "rogues" in culinary peas may be due to a similar type of disease.

The investigation of the mutants obtained from the jimson weed has been continued by Dr. Blakeslee, who reports as follows:

"Most intensive work has been carried on with the 'Globe' mutant, since this mutant can readily be recognized in the seed pans, but the same mode of inheritance seems to be characteristic of all the mutants of this type. The mutant character is transmitted to about one-quarter of its offspring, whether the female parent is fertilized by its own or by foreign pollen. The mutant character is transmitted not at all or but slightly through the pollen. Tests made last fall and winter showed that all the normal races have good pollen, with less than 5 per cent of the grains defective, while all the mutants of the globe type have a relatively high percentage of bad pollen-grains. The mutant 'New Species,' which differs from other mutants in breeding true and being largely sterile with other lines, resembles normals in that its pollen is relatively good. This mutant is one in which abnormal color ratios had been observed. It was believed that chromosome relations might furnish a clue to the abnormal behavior of the mutants in this species. Mr. John Belling has cooperated in a cytological study of our mutant variants. The work is still in progress, but some definite results have already been obtained.

"The 'New Species' turns out to be tetraploid, having 24 in contrast to 12 pairs of chromosomes, characteristic of normal races. Sufficient breeding work with this form has already been carried out to settle certain questions in regard to the behavior of the tetraploid chromosomes at the formation of gametes. Independent assortment of the chromosomes is demanded by the breeding results. Starting with a tetraploid plant that is heterozygous for a factor A and represented by the formula AA'aa', we expect its gametes to be AA', Aa, Aa', A'a, A'a', aa', if the chromosomes assort independently. If we disregard the primes and sum the types we have 1 AA + 4 Aa + 1 aa as the formula for both the male and female gametes produced by a tetraploid plant of the formula AA'aa'. Selfing such a plant, one should obtain the following: 1 AAAA + 8 AAAa + 18 AAaa + 8 Aaaa + 1 aaaa, or a ratio of dominants to recessives of 35 : 1. The AAAA plants should always breed true; the AAAa plants when selfed or back-crossed to recessives should give only dominants, but in later generations should give 35 : 1 ratios; the AAaa plants when selfed should again give 35 : 1 ratios and when back-crossed to recessives should give 5 : 1 ratios; the Aaaa plants when selfed should give 3 : 1 ratios and 1 : 1 ratios when back-crossed; and in later generations some 35 : 1 ratios should be expected from selfing individual plants of a 3 : 1 pedigree. By using the purple color of stem, which is dominant to green stem, we have been able to take records from the seed pans and in consequence have obtained relatively large numbers in our pedigrees. The results show that the inheritance of the purple color of stem in our tetraploid jimson is in accord with the theoretical expectation already described for independent assortment of chromosomes. Last year a tetraploid plant arose

in a pedigree heterozygous for spines and node number as well as for color. Although detailed field records have not yet been taken, the segregation of these other factors appears to conform to the expectation made out for the purple stem-color. Triple recessives have not appeared, but the theoretical chances of their occurrence are only 1 in 46,456 individuals in this generation. They should be easily obtained another year.

"So far as has been determined, the *Datura* mutants of the 'Globe' type seem to be due to the presence of an extra chromosome giving 25 instead of 24 chromosomes in the somatic cells. The gametes therefore would have 12 and 13 chromosomes. There appears to be some evidence that the extra chromosome is a specific one in each case. Apparently we have been able to identify in *Poinsettia* the mutant which has as an extra chromosome—the one carrying the determiners for purple and green stem-color. Five *Poinsettia* plants, heterozygous for purple and green, have, when selfed, produced pedigrees of which all the *Poinsettia* mutants are purple and the normals show purple and white in a ratio closely approximating 8 : 1. If these parent *Poinsettia* plants be considered to have the formula PPp, their female gametes should be P+Pp+P+Pp+p+PP or 2P+2Pp+p+PP. The male gametes represented by the pollen-grains should be the same, but, since the mutant character generally fails to be carried by the pollen, the effective male gametes may be considered to be 2P+p. Selfing *Poinsettia* plants of the formula PPp should therefore give all the *Poinsettia* offspring purple and 8 purples to 1 green among the normals, a result that was actually obtained. The matter is being tested further with this particular mutant and an effort is being made to discover which of the remaining mutants have as their extra chromosomes those carrying factors for known Mendelian characters. It seems inadvisable to report further than in a very tentative way on the Globe type of mutations in *Datura*, since the present stage of the work would not warrant any definite conclusions. It is obvious, however, that if the facts turn out to be what the present findings indicate, they may furnish the clue to much which has been unintelligible in this and certain other species."

Rudbeckia.—The breeding work on *Rudbeckia* has been discontinued by Dr. Blakeslee on account of the difficulties of technique involved in crossing them, and their decrease in vigor when inbred. The work on the inheritance of the two yellow cones in this species and their identification by chemical means has been written up and is now in press.

HEREDITY OF SUSCEPTIBILITY TO CANCER.

The importance to mankind of a knowledge of the hereditary factors in cancer can hardly be overestimated, and the theoretical interest of an analysis of the behavior of these factors is no less great. Dr. Little reports on his results in this field as follows:

"*Genetical factors involved in susceptibility.*—In 1916, Little, in collaboration with Tyzzer, reported on the inheritance of susceptibility to a transplantable carcinoma (J. w. A.) of the Japanese waltzing mouse. This tumor grew in 100 per cent of the Japanese waltzing mice inoculated, and in 0 per cent of the common non-waltzing mice. When these two races were crossed, the F_1 generation hybrid showed 61 out of 62 mice to be susceptible. The F_2 generation gave a very interesting result—only 3 out of 183 mice grew the tumor. At that time the results were explained on the basis of multiple Mendelizing

factors whose number was estimated at from 12 to 14. *Simultaneous presence* of these factors, themselves introduced by the Japanese waltzing race, was considered necessary for progressive growth of the tumor.

"Later, while working with a transplantable sarcoma (J. w. B.) of the Japanese waltzing mouse, results were obtained which showed what seemed to be a somewhat simpler quantitative condition of the same process. In this case the parent races and F_1 hybrids behaved as before, but the F_2 hybrids gave a total of 23 susceptible to 66 non-susceptible animals. It was previously estimated that from 5 to 7 factors were involved. In order to determine more closely the number of factors, new experiments were devised, as follows: F_1 hybrid mice, themselves susceptible, were crossed back with the non-susceptible parent race. This has during the past year given a back-cross generation whose susceptibility would depend upon the factors introduced through the gametes received from their F_1 parent. If one factor was involved, the ratio of gametes containing it formed by the F_1 animal to those lacking it would be 1:1; if two factors, 1:3; if three factors, 1:7; if four factors, 1:15; if five factors, 1:31; if six factors, 1:63; and if seven factors, 1:127. Susceptible to non-susceptible *individuals* would occur in the back-cross generation in similar proportions.

"The actual numbers obtained were 21 susceptible to 208 non-susceptible. This result may be compared with expectations on three, four, five, and seven factor hypotheses, as shown in table 9.

TABLE 9.—*Comparison of observed and various theoretical ratios of susceptibility and non-susceptibility in back-cross.*

	Susceptible.	Non-susceptible.	Ratio.
Expected 3-factor	28	201	1:7
Observed	21	208	1:99
Expected 4-factor	14	215	1:15
Expected 5-factor	7	222	1:31
Expected 7-factor	1.8	227.2	1:127

"The observed figures fall between the three and four factor hypothesis. The numbers are not large enough to give a definite test, but the F_2 generation already mentioned is interesting as a supporting line of evidence. If we compare this with the expectation, we find that the observed figures lie between the four and five factor hypotheses (table 10).

TABLE 10.—*Comparison of observed and various theoretical ratios in F_2.*

	Susceptible.	Non-susceptible.	Ratio.
Expected 3-factor	39	50	1:1.3
Expected 4-factor	29	60	1:2.1
Observed	23	66	1:2.8
Expected 5-factor	21	68	1:3.2

"In both cases the four-factor hypothesis figures are close and the three and five factor hypotheses are to be still considered as possibilities, though not probabilities. The six and seven factor hypotheses appear to be definitely eliminated.

"The sex chromosome has been eliminated as a probable carrier of any of the four factors, as follows: If mice, like other mammals, have the female XX and the male XY in formula, the use of susceptible Japanese waltzing males to form the F_1 animals used gives daughters carrying his X and sons his Y chromosomes. If, now, his *sons* only are used to produce the back-cross generation by mating with common non-susceptible females, all the chromosomes in the resulting animals will be derived from common non-susceptible mice and the male offspring would be all non-susceptible; but such is not the case. Unless, therefore, crossing-over between the X and Y chromosomes occurs frequently, any susceptibility factor borne in the X chromosome of the original Japanese waltzing males used has been eliminated.

"While further investigations are in progress, we may conclude provisionally that:

"(1) From three to five factors, probably four, are involved in determining susceptibility to the mouse sarcoma J. w. B.; (2) that for susceptibility the simultaneous presence of these factors is necessary; (3) that none of these factors is carried in the sex (X) chromosome; and (4) that these factors mendelize independently of one another.

"*Factors underlying growth of a transplantable mouse sarcoma (J. w. B.)*—A series of experiments was undertaken by Little to determine factors that underlie sarcoma growth. The 675 mice used in these experiments were of two races: (1) common non-waltzing animals of albino (a) and dilute brown (dbr) stocks, and (2) hybrids produced by crossing these common races with Japanese waltzing mice and then back-crossing the first-generation hybrid with the common non-waltzing parent race.

"The two races are very different biologically. Series N includes the common-stock mice unrelated to Japanese waltzing mice (the race in which the tumor originated and in which it grows freely). Common mice rarely, if ever, have shown progressive uninterrupted growth of the Japanese tumor J. w. B., although as Tyzzer and Little have shown there may be temporary growth of the tumor followed by its regression and eventual disappearance. Their behavior in the present series of experiments is very similar to that in the earlier series referred to.

"Animals of series B. C. (back-cross), on the other hand, have one of their grandparents a Japanese waltzing mouse of the same inbred race which gave rise to the tumor, and one parent a first-generation hybrid between the Japanese waltzing and common races. These first-generation hybrids will, as shown by Tyzzer and Little, grow the tumor as well as, if not better than, animals of the pure Japanese waltzing race. If, as seems certain, hereditary factors favoring growth of the tumor are introduced by the Japanese waltzing race, the B. C. generation has a direct opportunity to receive them, while the common race has not.

"Beginning with a date two weeks after inoculation, weekly observations were made upon all inoculated mice. The mice were examined individually by palpation, and the presence or absence of a mass noted. If a mass is present it is described, and if it is larger than a pinhead a sketch is made of it on the record sheet of the mouse.

"Thus weekly observations are made in the case of all animals up to and including the sixth week after inoculation. From that time on, observations are made upon only those animals showing a mass. In this way a diagrammatic representation is obtained of the gradual growth of the tumor as well as a record of its diminution and eventual disappearance, should this take place. The absolute size of the mass can not, of course, be very accurately determined, and is not to be considered at present. The Misses B. W. Johnson, E. E. Jones, and D. M. Newman have been of the greatest assistance in the tedious work of inoculation and observation of the mice.

"Mice were inoculated in ten age-groups: 2, 4, 6, 8, 10, 12, 14, 16, 18, and 20 or over days old, respectively. In calculating the amount of growth observed, a single observation is the unit employed.

"A short table will show the interesting difference between the albino stock mice (N) and those of the back-cross (B. C.) generation. The sign + denoted an observation showing a mass, the sign − one which is negative (table 11).

TABLE 11.—*Comparison of stock and back-cross mice.*

	+	−	Per cent.
Stock mice (N)	233	1,862	11.12±0.46
Back-cross mice (B. C.)	170	799	17.54± .83
Difference	......	....	6.42± .95

"The difference between the races is certainly significant, being almost seven times its probable error.

"If the mice in each series are divided into a younger (2 to 10 days old) and an older (12 to 20+ days old) group, according to their ages at inoculation, an interesting fact is brought out (table 12).

TABLE 12.—*Comparison of younger and older groups.*

	Per cent of observations showing growth.		
	Young group.	Old group.	Difference.
Stock mice (N)	12.87±0.6	9.49±0.6	3.38±0.85
Back-cross mice (B. C.)	13.77±1.05	21.58±1.28	7.81±1.65

"The differences between the two age-groups are in the opposite direction in the two series. When the data are analyzed according to sex, another point is brought out, namely, the fact that the females present certainly significant differences between the age-groups, while the males do not (table 13).

TABLE 13.—*Comparison of sexes and age-groups.*

	Per cent of observations showing growth.			Remarks.
	Young group	Old group.	Difference.	
Stock mice (N):				
Males	15.70±1.64	10.30±1.2	5.4 ±2.6	Probably not significant.
Females	19.46±1.31	9.39± .87	10.7 ±1.51	Significant.
Back-cross mice (B. C.)				
Males	14.51±1.51	15.38±1.55	0.87±2.46	Not significant
Females	12.12±1.76	25.74±2.07	13.62±2.71	Significant.

"The suggested explanation is that the females of the series in the older age-group reach sexual maturity earlier than the males, and in many cases at least do so during the period in which they are under observation. That the ovary increases its activity as an organ of internal secretion at the onset of sexual maturity is well known and affords an assurance that a more detailed differentiation of the tissues is possible. The true physiological nature of the individual expresses itself and the genetic factors, determining in the stock mice elimination of the tumor and in certain of the back-cross mice its growth come into full activity.

"It may be concluded that the onset of ovarian activity following the attainment of sexual maturity acts in mice as an important agent in determining the fact of successful implants of a mouse sarcoma. Thus in a race of a genetic constitution known to be unfavorable to growth of this tumor, the most stringent and efficient elimination is found in females old enough to be sexually mature. On the other hand, in a hybrid (back-cross) race, the females of sufficient age to be sexually mature show the highest percentage of tumor growth.

"Both these cases are explicable on the supposition that the internal secretions arising at the onset of sexual maturity are important agents in determining physiological differentiation of the tissues of the animal. This differentiation is merely the expression of its full hereditary physiological make-up. This in the non-susceptible race eliminates the tumor, and in the back-cross race, where certain animals have some or all of the factors determining susceptibility, encourages tumor growth."

"*Origin and propagation of adenocarcinoma dBrA.*—In March 1920 an adult female dilute brown mouse of a closely inbred strain of this color, which has been under observation for eleven years, showed a tumor nodule of spontaneous (*i. e.*, not inoculated) origin. Examination of sections of this nodule showed it to be an adenocarcinoma. Upon subcutaneous implantation, bits of this tumor dBrA have grown in all the animals (30) of the inbred race which were inoculated. Some two weeks after the tumor dBrA was observed, another adult female dilute brown mouse of the same inbred strain showed a spontaneous tumor. This upon section showed a structure indistinguishable from dBrA. It also was classified as an adenocarcinoma, dBrB. This has also grown in 100 per cent of the animals (20) of the closely inbred dilute brown race inoculated. It is to be expected that all the mice of the dilute brown race should after eleven years of inbreeding have a strikingly similar genetic constitution. This should find expression in the similarity of the nature and physiology of tissues as well as in other characteristics. It is, therefore, to be expected that bits of the transplanted tumor should persist in different individuals of this race, since, by inbreeding and the resulting approach to homozygosity, the conditions met with in homoplastic implants become more nearly identical with those characteristic of autoplastic implants.

"That the factors underlying growth of implants of one of these tumors (dBrA) were not generally distributed in all common mice was shown by its inoculation in 10 animals of an inbred yellow-and-black agouti race, unrelated to the dilute brown race in which the tumor originated. These 10 mice were negative and failed to grow the tumor.

"Another group of mice was available for inoculation. These were back-cross animals resulting from a pure dilute brown mouse crossed with an F_1 hybrid between a dilute brown and a Japanese waltzing mouse. All such mice therefore possessed one dilute brown parent which by hypothesis should be forming gametes of which a considerable preponderance had the factors necessary for susceptibility. Actually, of 24 mice inoculated, 20 showed progressive growth of the tumor dBrA, while two others showed temporary growth with regression and eventual disappearance. In its behavior, therefore, the tumor dBrA gives genetic results explicable on a similar basis to that employed in the case of the Japanese tumor. It is interesting to find supporting evidence from a race of common non-waltzing mice showing that the principles involved are not confined to any one race or group of animals.

"*Origin and propagation of adenocarcinoma dBrB.*—The tumor above described as dBrB grew in all dilute brown mice in which it was inoculated, even if dBrA was inoculated at the same time and in the same mouse.

"During the summer of 1920, Mr. L. C. Strong conducted experiments on the reaction of wild mice to implants of these two tumors. Each mouse was inoculated on the same day with dBrA on the right side and with dBrB on the left. The mice have been observed at weekly intervals, beginning at a date two weeks after inoculation. Those showing a palpable mass are designated +; those negative, −."

TABLE 14.—*Comparison of reaction of mice to tumors in dBrA and dBrB.*

Observation, post-inoculation.	Total mice.	dBrA.			dBrB.		
		+	−	*p. ct.* +	+	−	*p. ct.* +
2 weeks......	114	7	107	6.1	20	94	17.5
3 weeks......	74	4	70	5.4	12	62	16.2
4 weeks......	54	3	51	5.5	7	47	13.0
5 weeks......	42	1	41	2.3	3	39	7.1
6 weeks......	26	0	26	0.0	1	25	3.8
Total......	....	15	295	4.68 ± 0.8	43	267	13.43 ± 1.29

The difference between the percentages of observations showing indications in the two tumors is 8.75 ± 1.51 or 5.7 times its probable error. This demonstrates that even in the small number of observations recorded we have in the reaction to implants of the tumors a physiological test more delicate in its discrimination than is the histological test, which failed to show notable differences between the two tumors. The experiment indicates that reaction to tissue implants may be used as a comparative method which gives an extremely delicate test of physiological differences. Mr. Strong is also studying the effects of gonadectomy and splenectomy on growth of implants of these tumors and will continue the work during the ensuing year.

HEREDITY OF MENTAL AND PHYSICAL TRAITS IN DOGS.

A study has been undertaken on the method of inheritance of instincts and other traits in dogs. This work is under the immediate charge of Dr. E. C. MacDowell. On September 1, 1920, the laboratory possessed 7 male and 6 female adult Dachshunds and 14 pups. Four litters have been born, with the loss of only one animal, which died at birth. There were also 1 male and 3 young female English setters. All of the breeding animals are of standard-bred stock. Already much work has been done in testing instincts of the individual breeding animals, and some special methods of measuring strength of instincts have been worked out.

HEREDITY IN SHEEP, RABBITS, AND POULTRY.

The experiments on heredity of twinning and multinipples in sheep were continued. A new and young ram, born 1919, himself one of triplets, was used as a sire for the lambs born in 1920. There were 28 lambs born from 21 mothers, being a proportion of 1.3 lambs per

mother, as contrasted with 1.8 for 1919, 1.6 for 1917, and 2.2 for 1916. It is thought that this falling-off in percentage of twin births is due, in part, to the youth of the ram and, in part, to the poor nutritive conditions in which the ewes were found at tupping time. The cooperative sheep experiment with the New Hampshire Experiment Station, which experiment is primarily under the direction of Mr. E. G. Ritzman, is being continued. A joint paper by Ritzman and Davenport, "A comparison of some traits of conformation of Southdown and Rambouillet sheep and of their F_1 hybrids," was published during the year.

During the year about 80 chicks of the Silky and rumpless strains were hatched. Dr. George B. Jenkins made further studies on rumplessness and abnormal plumage of these strains.

Professor H. D. Fish, of Denison University, Research Associate at the Station, has made use of the facilities of the Station during the year to continue his remarkable series of rabbits which are being bred, largely, to get at the factors for spotting and coat color.

HEREDITY IN MAN.

Studies on this topic by members of the station are considered under the Eugenics Record Office.

SPECIES HYBRIDS.

More and more, in both plants and animals, the subject of sterility and the importance of lethal factors, factors that kill, is assuming great prominence. This leads to the subject of sterility between distinct species. As a guest of the Station, Mr. John Belling has been paying special attention to the nature of species hybrids in plants and the mode of inheritance of their characters, especially of partial sterility. Mr. Belling is working especially on the genus *Canna*, which contains numerous species that are propagated as clones. It appears that most of the *Canna* clones are heterozygous and much affected by imperfect pollen-grains, which can be readily distinguished from those that are perfect. The topic has important theoretical bearings on the origin of species, since distinct species are usually characterized by some degree of sterility.

GERMINAL AND SOMATIC VARIATIONS.

MUTATIONS IN MUCOR.

A report on mutations by Dr. Blakeslee in vegetatively pure lines of mucors is in press. In addition to a number of mutants of various types already reported, one mutant from a hermaphrodite has been cultivated in pure vegetative lines since 1913, but has consistently failed to show sexual spores since its first discovery. That it is still a hermaphrodite is obvious by its sexual reactions with both test plus (+)

and minus (−) races of diœcious species and by the fact that it has given rise to another distinct mutant which does produce zygospores, although in scanty amount.

THE VASCULAR ANATOMY OF VARIANT BEAN SEEDLINGS.

Dr. Harris has, for some years, been breeding strains of beans with remarkable abnormalities that appear even in the seedling stage. Since 1917 a detailed study of the vascular morphology of these variant bean seedlings (in comparison with the normal) has been under way in co-operation with Professor E. W. Sinnott, of the Connecticut Agricultural College, and with the assistance of Dr. John Y. Pennypacker and Mr. G. B. Durham. A first paper, covering the problem of number and variability of bundles in the different regions of dimerous and trimerous seedlings is now in press. The results of this study show that external differentiation, such as that which characterizes dimerous and trimerous seedlings of *Phaseolus vulgaris*, is accompanied by profound differences in internal structure. They show further that anatomical characters, which by morphologists in general have been regarded as relatively stable, may be highly variable, even in series of individuals which are genetically highly homogeneous. Furthermore, the results show that variability in morphological characters is not a constant for the plant as a whole, but may differ from region to region or from organ to organ. In the seedling types investigated, for example, hypocotyl and epicotyl differ widely in the variability of bundle-number. Furthermore, differences in variability from organ to organ or from region to region are not constant, but may be conditioned by other morphological features. Thus, the variability of bundle-number of normal seedlings is higher in the hypocotyl than in the epicotyl. In seedlings with three cotyledons and three primordial leaves just the reverse is true. Other phases of the problem will be discussed in papers nearly ready for publication.

THE ORIGIN OF PIEBALD SPOTTING IN DOGS.

During the past year Dr. Little has published a note concerning the occurrence of piebald mutants in thoroughbred Scottish and Airedale terriers. These two breeds have been selected for generations for absence of white spotting and are unknown in piebald forms. The sudden appearance of spotted mutants with a considerable amount of white demonstrates that in some forms at least clearly piebald forms can arise without gradual selection from minute beginnings.

ALTERATION OF THE QUALITY OF A POPULATION BY SOMATIC SELECTION.

Dr. Banta has completed, ready for press, work upon selection for reactiveness to light of *Entomostraca* of the order Cladocera. The study has a special interest in being, apparently, the first extensive investigation of selection of a purely physiological character. As

stated in last year's report (p. 132), one line (line 757) showed a marked divergence in the strains selected for greater and for less reactiveness respectively. Further analysis has brought out additional points: (1) Environmental influences, which much affected the mean reaction-time in all the lines studied, in the line in which an unmistakable selective effect was obtained, merely served to cut down the divergence temporarily; (2) the result, divergence in reactiveness, is due to changes in the reactiveness of both the high and low strains of the line affected; (3) the form of the reaction-time curves indicates that the effect was cumulative and that the divergence was still increasing when selection was discontinued; (4) the result appears to be due to many small genetic changes; (5) the two strains of the line are indistinguishable, except in their differences in behavior to directive light stimulation; (6) the divergence is permanent, or at least persisted 112 generations (32 months) after selection was discontinued.

EFFECT OF CAVE CONDITIONS.

For some years Dr. Banta has been breeding animals under cave conditions to ascertain the change in color, or possibly form, that may result, in the hope of throwing some light upon the extraordinary characters of cave animals. Amphipods are breeding freely under our cave conditions. Additions to our cave fauna are being made each spring.

MUTATIVE COLOR CHANGES IN FLOUNDERS.

An observation which has interested Dr. Banta concerns the occurrence of pigment on both sides of the common flounder in Cold Spring Harbor. During this summer apparently about 20 per cent of the fish, which are presumably of this year's (early spring) hatch, possess more or less pigment on the side upon which the fish rests and which is normally entirely without pigment. Fishermen agree that they had never commonly seen "flatfish with black on both sides" until the present season, though they claim to have seen them occasionally before. In an examination of all the larger flatfish available (only a few, however) which were presumably of a previous year's hatch, only one with any trace of pigment on the under side was found. The pigment in this case consisted of a mere trace on the caudal fin and in the lateral-line region of the tail. The pigment on the under side in the smaller fish varied all the way from a mere trace caudally to complete pigmentation of the under side, except for the head and a small portion immediately posterior to it. All specimens were fully pigmented on the upper side, which bears both of the eyes.

PHYSIOLOGY OF REPRODUCTION AND DEVELOPMENT.

EFFECT OF VARIATIONS OF OXYGEN-SUPPLY ON AVIAN DEVELOPMENT.

In connection with his sex studies, Dr. Riddle has found it necessary to undertake or to continue the examination of certain factors or con-

ditions of avian development and reproduction. The more important of his results are the following:

It has been found that the failure of some birds' eggs to hatch is caused by a hitherto unsuspected and quite unapparent inadequacy of the egg-shells. Shells which do not break may, nevertheless, permit a too rapid ingress of oxygen and egress of water, and this certainly results in the death of many embryos. Undoubtedly this discovery, which is of much interest in our sex and fertility studies, will become of real importance in the poultry industry, where probably millions of incubated eggs with failing embryos are annually lost from this source.

Two attempts have been made to learn a treatment for birds which produce eggs with defective or inadequate shells. These attempts have been essentially unsuccessful in the main purpose, but have developed some useful facts. In collaboration with Mr. Martin C. Hanke, it was found that the feeding of additional soluble calcium salts—calcium lactate and calcium phosphate—affects but very slightly the amount of calcium which laying doves utilize in the formation of the egg-shell. It is concluded that the inadequate shells are probably not primarily due to a lack of soluble-calcium compounds in the food of the bird.

In view of the above result, it was thought advisable to investigate the mechanism of control of the oviducal secretions of the bird. With the assistance of Mr. Cecil V. King, the effects of atropine, nicotine, and cocaine upon the production of albumen and shell-material was extensively studied. The results lend no hope to a possible stimulation of excess secretion by means of drugs. An effect (somewhat reduced secretion) could usually be obtained with appropriate dosage of cocaine and nicotine, but Dr. Riddle concludes that either the oviducal secretions of the bird are largely independent of the sympathetic nerves or that the drugs which act most pronouncedly on these nerves of the mammal do not have an essentially comparable action in doves.

Finally, in connection with the study of the effects of increased and decreased pressures of oxygen on embryos of the two sexes, Dr. Riddle has completed an investigation of the necessary gaseous environment of avian embryos. In general, it is found that for oxygen the lower limit of life and development, for 24 to 48 hour periods followed by return to normal air, is about 10 per cent and the upper limit about 96 per cent. The upper limit for carbon dioxide, in connection with increased pressures of oxygen, is not far from 10 per cent, which is more than 300 times the amount normally present in air. The age of the embryo is an important modifying factor. It has also been found that the higher pressures of oxygen result in the complete disappearance of hemoglobin from the blood of embryos of about 2 days of development, and that abnormalities and "monsters" are often produced in embryos of less than 1.5 days. A further study of the conditions and nature of these changes is being made.

PHYSIOLOGY OF FECUNDITY IN THE DOMESTIC FOWL.

Biometric investigations of the physiology of egg production and the inheritance of egg production in the domestic fowl have been continued by Dr. Harris in cooperation with three of the agricultural experiment stations. These studies have to do with the prediction of future egg production from the record of short antecedent periods, with the relationship between first and second years' production, and with the correlation between the record of mother and daughter. Manuscripts giving the results of some of this work are in an advanced state and will be ready for publication shortly.

OTHER INVESTIGATIONS.

STUDIES ON THE PHYSICO-CHEMICAL PROPERTIES OF VEGETABLE SAPS.

These investigations, which have been under way for the past several years in cooperation with the Department of Botanical Research, have been continued and considerably expanded during the year by Dr. Harris and his assistants. He reports progress along the following lines:

"(1) *Osmotic concentration and electrical conductivity of sap properties in relation to growth-form.*—A first paper on the problem of the electrical conductivity of the leaf-tissue fluids of the Cold Spring Harbor region, to be published with Professor R. A. Gortner, of the University of Minnesota, and Mr. John V. Lawrence, of the University of Chicago, is now ready for press. The results of this investigation, in connection with others carried out earlier, are of considerable interest in relation to the much-discussed problem of the evolution of woody and herbaceous growth-forms. Earlier studies in the Jamaican montane rain forest, in the Arizona deserts, and in the mesophytic habitats of the north shore of Long Island have shown that the osmotic concentration, as measured by the cryoscopic method, is far higher in the leaf-tissue fluids of ligneous than of herbaceous species. As a result of these studies a definite physico-chemical difference in the leaf-tissue fluids was shown to be associated with the differentiation in growth-habit. In the present paper it is shown, on the basis of a large series of determinations in the various non-halophytic habitats of the north shore of Long Island, that the specific electrical conductivity of the expressed leaf-tissue fluids of ligneous species is lower than that of herbaceous species. Thus, while the concentration of total solutes is higher in the tissue fluids of ligneous species, the reverse is true for ionized electrolytes. An investigation of the correlation between freezing-point lowering, Δ, and specific electrical conductivity, k, shows that in a series of species there is practically no relationship between these two properties of the expressed tissue fluids.

"(2) *The chloride content of the tissue fluids of halophytic plants.*—The osmotic concentration of the tissue fluids of halophytic plants is generally higher than that of comparable growth-forms in non-saline habitats. This may be due either to the direct absorption of salts from the soil or to the synthesis of larger quantities of organic substances. The solution of this problem is of considerable importance in relation to the more general problem of adjustment and adaptation. Considerable attention has, therefore, been given to the determination of the chloride content of plant saps in relation to osmotic concentration. With the cooperation of Mr. John V. Lawrence, of the Department of Physiological Chemistry of the University of Chicago, satis-

factory methods for the collection and analysis of large series of samples have been worked out. The analyses of the extensive series of samples collected with the assistance of Messrs. Lawrence and Hanke in Dr. Harris's work along the Atlantic Coast in 1919 (Year Book Carnegie Inst. Wash., 1919, 143) has now been completed and the results will be presented shortly.

"(3) *Sap properties of the vegetation of the Lake Bonneville Basin.*—The most extreme concentrations of the soil solution to which plants are exposed in their struggle for existence are found in the basins of ancient lakes. In such regions striking peculiarities of structure bear witness to the evolutionary changes from the plant structures typical of mesophytic regions which have been necessitated by the special environmental conditions. Of the available regions, the basin of ancient Lake Bonneville, of which Great Salt Lake and Sevier Lake are small remnants, affords the best opportunities for investigation, both because of the wide range of environmental conditions and the relative accessibility of the habitats. Furthermore, the classic geological studies by Gilbert and the pioneer work on the indicator plants of alkaline regions by Kearney, Briggs, and Shantz and their coworkers makes coordination with other investigations highly desirable. The Biophysical Laboratory and the Office of Drought and Alkali Resistant Plant Investigations of the Department of Agriculture asked Dr. Harris to cooperate in the investigation of the physico-chemical properties of the vegetation of this region, and he was absent from Cold Spring Harbor from May 20 to September 7, 1920, while engaged in this and associated projects. Mr. Andrus T. Valentine, of Cold Spring Harbor, served efficiently as field assistant during the entire period. Dr. R. A. Gortner, professor and chief of the Division of Agricultural Biochemistry of the University of Minnesota, and Mr. Walter B. Hofmann, instructor in agricultural biochemistry at the University of Minnesota, joined in the field operations until August 1. Operations were then transferred to the Cooperation Testing Station at Sacaton, Arizona, where facilities were placed at Dr. Harris's disposal.

"In the Great Salt Lake region about 750 determinations of osmotic concentration and specific electrical conductivity were made. Samples were also preserved for chloride determination. These was chiefly on native vegetation, but a considerable number was based on cereal varieties under investigation on the dry-farming substation of the Utah Agricultural College and the Office of Cereal Investigations of the Federal Department of Agriculture at Nephi, Utah. Thanks are due to C. R. Ball, of the Department of Agriculture, and to F. S. Harris, Director of the Utah Agricultural Experiment Station, for permission to obtain material from this valuable series of cultures; also to Mr. Bracken, the superintendent of the Nephi substation, for assistance in obtaining materials. At Sacaton it was possible to secure valuable determinations on the halophytic vegetation of the Gila River Valley, and also to supplement our series of determinations on loranthaceous parasites by determinations of electrical conductivity as well as osmotic concentration. Dr. T. H. Kearney also placed his culture of upland and Pima Egyptian cotton at our disposal, and it was possible to compare the sap properties of these two types and of their F_1 hybrids under as nearly as possible identical conditions. Incidentally it may be noted that Pima Egyptian cotton is probably the plant mutation of the greatest economic importance, a $20,000,000 crop having been grown in 1919. A crop of 200,000 acres, the progeny of an original mutant individual, is now in the field. The results of Dr. Harris's determinations in the field and in accessible cultures will be worked up as rapidly as the computing and clerical force available will permit."

STATISTICAL THEORY OF PLOT TESTS.

Studies of field heterogeneity in relation to the problem of the accuracy of plot tests of new varieties have been under way at this Station for the past several years. Some time ago the Office of Western Irrigation Agriculture of the United States Department of Agriculture asked our cooperation on this problem and work has since been conducted largely on the data and with the support of the Department of Agriculture. A first paper, in which substratum heterogeneity was shown to be a universal factor of significance in plot tests, has been published by Dr. Harris (Jour. Agr. Res., vol. XIX, 279–314, July 1, 1919), and another, in which the permanence of the differences in the small plots of an apparently uniform field and the influence of preceding upon subsequent crops are discussed, is now ready for publication.

COOPERATIVE WORK ON HUMAN NUTRITION.

Studies of variation and correlation in the basal metabolism of the individual subject have been under way by Dr. Harris, in cooperation with the Director of the Nutrition Laboratory of the Institution. The results are practically ready for publication.

EUGENICS RECORD OFFICE.

STAFF.

During the year ending September 1, 1920, the Eugenics Record Office has gradually resumed its former activities, though with diminished personnel, because of limited funds. Dr. H. H. Laughlin, who has served effectively as superintendent of the Office from the beginning, was given leave of absence for one year from June 1 and Dr. Banker has served in his stead. Dr. Arthur H. Estabrook was honorably discharged from the service of the government in April and took up again his investigation of the Ishmaelites, with his headquarters at Indianapolis. Dr. Banker has continued his investigations into heredity of aristogenic families. Dr. Wilhelmine E. Key returned to the Office for a few months in the autumn and winter of 1919–20, but is now located with the Battle Creek Sanitarium. Miss Nelson has served continuously as archivist.

HEREDITY IN ARISTOGENIC FAMILIES.

Dr. Banker's work proceeds somewhat slowly, because he is without clerical assistance and because of the difficulty in filling all the gaps in the biographical records. He has been confronted with the difficulty of expressing quantitatively the mental grade of individuals. In the case of college graduates of the last three or four generations it is possible to obtain an approximate relative grade of intellectual attainment, but for non-college people there is no basis for comparison. From the data available one forms an impression of greater and less ability and may arrange these crudely under an arbitrary scale, but it is impossible to draw any definite lines to the scale and equally impossible to group individuals into any definitely graded categories.

Also, we are far from being in a position to make a Mendelian analysis of the hereditary elements of the genes involved in an eminent author, poet, or popular orator. Psychology has not progressed far enough to aid in this matter. Indeed, it seems probable that the genetical analysis will aid the psychologist.

Nevertheless, Dr. Banker has obtained some significant facts from the study of an extended network of closely interrelated families. The network consists of a portion of the descendants of one couple through seven or eight generations, together with the blood relatives of these descendants for usually three or four generations. Lines in which there were evidently no college graduates have been dropped. The material so far accumulated contains more or less complete records of 3,538 individuals, of whom 518 were college men, or 14.6 per cent. This is, of course, too high a proportion for the whole network, because of the dropping of those lines which contain no college-bred persons. However, it gives a true percentage for those lines in which there are

one or more college men, and may be used as a basis of comparison within that range. The base, 3,538, includes all recorded individuals, a very large proportion of whom could not possibly have had a college record. Such are practically all the females, since in former years college courses were not open to women, and those males who died before the age of, say, 20 years. A more correct working-base would, therefore, be found by confining ourselves to the eligibles, that is, all men who have attained the age of 20. At present it is possible only to approximate the number of eligibles, which appears to be about 1,500, of whom, therefore, 34.5 per cent were college graduates. Among these, however, some lines show a much higher incidence of college men than others. Thus, in one branch, which we may designate as the W branch, there are more than 180 related individuals, of whom there appear to be not more than 12 who are college men, making less than $6\frac{2}{3}$ per cent, and in reality probably less than 1 per cent, since a large portion of this branch has been dropped because entirely lacking in college graduates. Of these 180, about 65 were eligible for college, hence something less than 18.5 per cent of those who could have gone to college actually went.

In the closely related G branch, from which scarcely any were dropped because of lack of college men, we have about 615 individuals, of whom 306 were eligible for college and about 121 actually attended, making thus 19.6 per cent of the whole branch, or 39.5 per cent of those eligible, that actually went to college. Other branches would show similar wide variation.

Moreover, comparing the W and G branches as to eminence, we find that, of the 12 W's who went to college, one is in Who's Who in America (vol. 10) and one in National Cyclopedia of American Biography, making $16\frac{2}{3}$ per cent of the college men of this branch who attained to sufficient distinction to be included in one of these publications. Of the 121 in the G's who actually entered college, 25 are mentioned either in the National Cyclopedia of American Biography or in Who's Who in America (vol. 10), making 20.6 per cent of the college men in this branch who attained to this degree of distinction. These facts appear to indicate that in the G branch we are dealing with a group of higher average intellectual ability than in the W branch.

PLURAL BIRTHS.

The Director attempted to secure light on the matter of plural births, especially twinning, in man. This is a matter of considerable interest, since about 1 per cent of all human births are twin births. These twin births are of two types, namely, those derived from two eggs ovulated simultaneously or nearly so, and those derived from a single egg which has formed two embryos. In the former case, each embryo is enveloped in its own chorion; in the latter, both embryos are enveloped

in one and the same chorion. Frequently a mother will have more than one pair of twins, a condition that may be called repeating. This phenomenon indicates a structural or physiological condition of the ovary which readily permits double ovulation. It is easy to understand how such an idiosyncrasy of the mother would tend to reappear in her daughter and thus the tendency to twinning show itself as a hereditary trait.

A statistical study of the close relatives of twin-repeating mothers, combined as a population, shows that in this population the ratio of twin production rises to 4.5 per cent, which indicates that such mothers belong to strains in which the factors for twinning are four times as effective as in the population at large. If, on the other hand, one considers as a population the close relatives of fathers of twins, then one still finds that the incidence of twins in this selected population is much above that in the population at large, namely, 4.2 per cent, a ratio nearly as high as that found for the relatives of the mothers. These proportions, calculated from the extensive records of the Eugenics Record Office, lead to the inquiry: How is it possible that there shall be a paternal inheritance in twin production that is as real, and nearly as potent, as the maternal. Also, the tendency for twin production is even stronger in identical than in two-egg twins, since the rate of twin production in families that produce identical twins is about 13 per cent.

The frequently denied possibility of inheritance of twinning through the father's side of the house depends on a tacit assumption which seems never to have been challenged by students of twin inheritance. This assumption is that the determining, essential fact in twin production as contrasted with single-birth production is the constant double ovulation in the first case and the constant single ovulation in the second. Whenever two eggs are simultaneously ovulated at a period when fertilization occurs, there will be twins. Under such an hypothesis it will be difficult to understand how the results are influenced by any tendency toward twin production from the father's side of the house.

Where the above hypothesis, however, fails is that about 8 per cent of ovulations are double, according to counts made by Leopold and other gynecologists. Thus the proportion of twins actually born is less than one-fifth, probably only one-seventh, as great as the proportion of double ovulations. To secure light on the question of what has happened to reduce the proportion of twin births so far below that of twin ovulations, a comparison has been made in the uteri of pregnant swine between the number of embryos in the course of development and the number of recent corpora lutea, each one of which indicates one ovulation. A preliminary study made during the winter revealed that there was a regular deficiency of from one to seven advanced embryos, as compared with the number of corpora lutea. During the

summer Dr. George W. Corner, jr., of the Johns Hopkins Medical School, assisted by Mr. Clyde E. Keeler, of Denison University, extended this statistical study into several hundred pregnant uteri. It appeared from all of these counts that nearly 98 per cent of the eggs ovulated enter the Fallopian tubes. Only about 80 per cent, however, are developing during the second month, and only about 70 per cent develop to the last third of pregnancy. Probably not more than two-thirds of the eggs ovulated result in pigs born alive. Just what happens during the first month of pregnancy which should cause the failure of so many eggs to develop is yet uncertain. Probably a certain proportion of the eggs are not fertilized. It is certain that of the fertilized eggs a certain proportion, which may lie between 10 and 20 per cent, proceed along their development to different points and then die. Similar blighted fetuses have been commonly found by obstetricians, and scores of cases of blighted twin fetuses are recorded in the literature. Also, as is well known, miscarriages and stillbirths are fairly common among humans, of which an important cause is apparently sheer inability to continue development because of the internal weakness of the embryo. Children who are born are already a selected group from among those whose development has been initiated. Such incapacity for development has been observed by geneticists in a large number of cases, and the category of lethal factors which inevitably prevent further development is now well recognized. Such lethal factors probably correspond to gross variation in essential visceral organs and run parallel to such gross variations of external organs as cleft palate, microphthalmia, and the absence of appendages. Now, such lethal factors may be brought into the zygote by the egg alone, by the sperm alone, or by both. They are not found in all germ-cells; it may be only in a small proportion of them. When they occur in the gametes of both consorts, small families, with some feeble children, may be expected; but when absent in the germ-cells of both parents, then, in a good environment, the fertilized egg will develop vigorously, with good prospects of reaching maturity. Now, it is in such families that any tendency toward double ovulation will be expressed in the production of healthy twins. This accounts for the long-known statistical fact that the proportion of twins is greater in highly fecund families than in those that produce few offspring. Also, among humans there is probably a frequent failure of fertilization of both eggs, resulting in a development of only one of a potential pair. The preceding considerations make it clear where the male factor enters in twin production; for the father, as much as the mother, determines whether both of a pair of simultaneously ovulated eggs shall be fertilized, and whether or not they shall receive lethal factors.

The statistical studies made on the relation between number of corpora lutea and number of embryos have been greatly extended by

Dr. Corner during the summer, and he has been able to establish the fact that there is in hogs an internal migration of ova from one horn of the uterus to another. He finds also a strong tendency, through this mechanism, to establish an approximate equality of embryos in the two horns, even when the disparity in the number of corpora lutea in the ovaries is very great.

SEX-LINKED LETHAL FACTORS IN MAN.

Dr. C. C. Little, with the cooperation of Miss Marion Gibbons, has prepared for press a paper on the statistical evidence of the occurrence of sex-linked lethal factors in man.

Sex-linked factors, other than lethals, have long been known in man. Among these, two genes which have been especially well studied are those for hemophilia and for color-blindness. The genes for these characters and their normal allelomorphs are carried in the X or sex chromosome. Since sex-linked lethals if they exist will also be carried in the sex-chromosome, certain of them may be closely linked with either of these genes or with their normal allelomorphs, according to the nature of the gamete in which they originate. If one of them occurs in a chromosome in which the gene for hemophilia is carried, it will, if it be closely linked with that gene, eliminate all the males, which would otherwise be hemophilic except in case a cross-over occurred. The same is true for color-blindness. Families in which such a condition was found might continue for several generations without giving a hemophilic or color-blind individual because of rareness of cross-overs. Such families would, therefore, not be recognized and would not be included among those selected to show the method of inheritance of these traits.

If, however, the lethal factor were linked with the normal allelomorph of these genes, normal sons would appear only when crossing-over occurred. These families would show a striking excess of hemophilic or color-blind males, as the case might be, and would, of course, be included in any study of the inheritance of these traits which might be made with other families in which no sex-linked lethals occurred. If a sufficient number of such families were, by chance, included in any mass of statistics on the inheritance of these traits, they should produce in the data a significant excess of hemophilic or color-blind males above the expected 1:1 ratio.

To test this matter, data at the Eugenics Record Office, as well as in Bulloch and Fildes's work on hemophilia and in Nettleship's work on color-blindness, have been tabulated and analyzed. Dr. Sewall Wright had previously tabulated the data in Bulloch and Fildes, and his data, which have very kindly been turned over to Dr. Little, are included in his figures. He has developed also a formula for calculating the number of abnormals (bleeders or color-blind) to be expected on

a 1:1 ratio basis in families of different sizes. This formula has been used in the calculations herewith appended (tables 15 and 16).

TABLE 15.—*Hemophilia.*

No. in family.	No. of families.	No. of males.	No. of bleeders.	No. of bleeders expected.	One certain bleeder extracted from each family.		
					No. of males.	No. of bleeders.	No. of bleeders. expected.
2	82	164	128	82	82	46	27.3
3	124	372	250	186	248	126	88.5
4	75	300	169	150	225	94	85.0
5	42	210	136	105	168	94	66.3
6	26	156	81	78	130	55	53.3
7	27	189	100	94.5	162	73	68.2
8	7	56	31	28	49	24	21.1
9	3	27	13	13.5	24	10	10.5
10	1	10	10	5	9	9	4.0
11	2	22	5	11	20	3	9.0
12	3	36	17	18	33	14	15.0
13	1	13	4	6.5	12	3	5.5
Total....	393	1555	944	777.5	1162	[1]551±11.05	543.7

The difference between the expected and observed numbers of bleeders is an excess of "observed," which is 8.8 times its probable error.

The data from pedigrees of color-blindness are much more meager, but are interesting in support of the figures previously quoted in the case of hemophilia.

TABLE 16.—*Color-blindness.*

No. in family.	No. of families.	No. of males.	No. of color-blind.	No. of color-blind expected.	One certain color-blind extracted from each family.		
					No. of males.	No. of color-blind.	No. of color-blind expected.
2	34	68	50	34	34	16	11.32
3	32	96	64	48	64	32	24.84
4	19	76	44	38	57	23	21.54
5	3	15	9	7.5	23	6	3.74
6	9	54	26	27	45	17	18.4
7	4	28	16	14	24	12	10.1
Total....	101	337	207	168.5	236	[1]106±5.15	89.94

The difference in this case is 3.1 times its probable error and is probably significant.

Another indication of the presence of sex-linked lethal factors is to be expected when the sex-ratio of families in which all the males are either hemophilic or color-blind are contrasted with families in which

[1] The ± value given represents the fluctuation in the actual number of hemophilic males, due solely to chance. On the basis of this value the actual number observed may be compared with the theoretical expectation as indicated.

part of the male offspring are normal. If the excess of hemophilic and of color-blind males is due to sex-linked lethal factors, families in which all the males are hemophilic or color-blind should include among them a considerable number in which this condition is due to linkage of the sex-linked lethal with the normal allelomorphs of hemophilia and of color-blindness. This should be accompanied by a relative excess of females in which no sex-linked lethals are present. Table 17 shows the totals for the four categories of families in question:

TABLE 17.—*Sex-ratio.*

	Males.	Females.	Ratio males to 100 females.	Difference.
All males hemophilic	413	337	122.55±2.73	35.26±3.39 (10.4×P.E.)
Some males hemophilic	1070	678	157.81±2.02	
All males color-blind	114	100	114.0 ±4.4	30.62±6.52 (4.6×P.E.)
Some males color-blind	184	119	154.62±4.83	

In both cases, although the data are gathered from very different sources, there is a significantly lower sex-ratio in the matings where it is to be expected.

We may, therefore, conclude that statistical analysis of human pedigrees of hemophilia and color-blindness indicate strongly that sex-linked lethal factors are present in man. Only detailed long-time investigations covering several generations of unusually prolific families can furnish additional proof.

HEREDITY OF HAIR, EYE, AND SKIN COLOR, AND HAIR FORM.

The Director has spent some time in securing additional and improved data on the family recurrence of peculiarities in pigmentation and hair form. Acknowledgment is made of the courtesies of the superintendent and principals of the Huntington schools and of the principals and instructors in biology at Girls' High School and Erasmus Hall, Brooklyn, and Evander Childs High School, the Bronx, for co-operation in this study.

MUSICAL FAMILIES.

Some months ago Professor C. E. Seashore, of the State University of Iowa, invented a method of expressing quantitatively variations in sense of pitch, intensity, time consonance, and tonal memory. Tests of these capacities were made by the use of phonograph records prepared in his laboratory. After conferences with Professor Seashore in 1919, it was decided to ask the Institution for an appropriation to enable his student, Miss Hazel M. Stanton, to make tests on musical families in New York, Boston, and vicinity, and this was granted. She

accordingly made such studies from February to June 1920, and has deposited the results with the Office. Of the M family group a pedigree chart including 78 individuals was prepared, and of these 11 were given the standard test. Of the L family there are 38 individuals recorded, of whom 6 were tested. Of the B family 77 individuals are recorded and 12 tested. Of the K family 78 individuals are recorded and 8 tested. Of the S family 113 individuals are recorded and of these 21 tested. The results are being analyzed.

THE FAMILY OF ISHMAEL.

Dr. Arthur H. Estabrook is continuing his studies on this group, continuing the work of Mr. MacCulloch of a generation ago. The more important subfamilies of the group have been completely studied and written up for final use. Many smaller families, closely connected with these, have been studied; they are now being worked up to final form. Pauperism seems to be the most important characteristic of this group; and the feeble-mindedness is, in general, of the higher grades. The other anti-social traits are closely allied to the feeble-mindedness. In connection with this pauperism, the report will include a study of the social forces at work here in the past. Approximately 10,000 individuals are under study.

OTHER FIELD WORK.

Dr. Elizabeth B. Muncey has been carrying on field-work on twin-producing families and, incidentally, on other families occurring in the locality in which she has been working.

LIBRARY WORK.

Miss Mabel L. Earle has continued to furnish extracts of the literature on special subjects, as required for the use of the Office. She spent three months at the Surgeon General's Library in Washington, abstracting literature which was not available in the Boston and New York libraries. Miss Earle spent some time at Cold Spring Harbor in work upon the library here. She has also sent in several hundred sheets of typewritten abstracts on various topics, especially on those relating to human reproduction and to twinning. Dr. Muncey has also made abstracts of the literature on twins.

INBRED COMMUNITIES.

A further analysis of the data obtained on the populations of certain island communities has been made by Miss Mary M. Sturges. It is hoped that during the autumn of 1920 some additional field-work to clear up certain remaining points will be made.

ANTHROPOLOGICAL STUDIES IN THE ARMY.

As indicated in the last report, a "First study of the records on drafted men and the defects found in them" was published by the

Surgeon General's Office in June 1919, in collaboration with Lieutenant-Colonel A. G. Love. In November 1919 there was issued, in collaboration with Lieutenant-Colonel Love, "Defects found in drafted men." The first edition consisted of 359 pages of text and did not include the extensive appendix. In the summer of 1920 the printing of the full book, including about 1,600 pages with the tables, figures, and plates, was authorized, and it has since been issued from the press. This work dealt with the defects found in 500,000 men who were rejected by draft boards on physical grounds and about 2,000,000 recruits who were examined also at military camps. It is impossible to summarize a statistical work here. It may merely be stated that the incidence of each of the principal groups of diseases in the military population was analyzed; that the incidence of these diseases in the different states was considered; and the relation of these diseases to classification in the military service was discussed. The whole country was divided into 155 geographical sections, partly based upon the nature of the population and certain physiographic features. The distribution of defects in each of these different sections is analyzed. Similar sections are then consolidated into larger groups, such as agricultural, manufacturing, mining, desert, mountain, maritime, largely Scandinavian, largely German and Austrian, largely of Scottish origin, and so on. Also, the comparative distribution of defects is given for urban and rural districts. The selected cities showed about 15 per cent more of defect than did the rural districts. This excess of urban defects is largely determined by the excess of flat feet in urban districts. There is also in the cities an excess of underweight, inflammation of the middle ear, errors of refraction, goiter, pulmonary tuberculosis, defective teeth, and syphilis. Defects of the rural districts are largely influenced by the racial fact that the negro population is more prevailingly rural than the white population. The rural districts exceed the urban in hereditary congenital defects, partly due to the differential migration away from rural districts of those without such defects and partly to the more frequent consanguineous matings in a rural population with such defects. The rural districts, also, show an excess of defects arising from accidental injuries.

In summary, the northeastern part of the country appears to be characterized by congenital defects and those of city life. The Northwest is characterized by deformities due to accidents, by goiter, and by flat-foot. The Southeast is characterized by venereal diseases, hookworm, and similar other complications, including blindness of one eye, arthritis and ankylosis, underweight, mental defect, emotional disturbances, pellagra, hernia, loss of upper extremity, and bullet or other wounds. The Southwest is characterized by tuberculosis, drug addiction, hypertrophied tonsils, and hernia. The northern central area is contrasted with the southern central by having more goiter,

less tuberculosis, much less venereal disease, more variocele and more varicose veins, more valvular disease of the heart and cardiac hypertrophy and dilation, more deficient teeth, more psychasthenia and constitutional psychopathic states. It is characterized by more otitis media, errors of refraction, diabetes, curvature of the spine, defects of genitalia, and weak feet, but less epilepsy, blindness of one eye, pellagra, loss of upper extremity, bullet and other recent wounds, underweight, and deficient chest measurement.

STERILIZATION LAWS.

Dr. H. H. Laughlin, superintendent of the Office, completed in April a manuscript comprising 1,300 pages on "Eugenical sterilization in the United States," and this is now awaiting publication. This work treats the historical, legislative, legal, administrative, surgical, physiological, and eugenical phases of the subject. It contains a complete record and a careful analysis of all legislation and litigation relative to the matter; it provides, also, a complete statistical and historical, and, so far as possible, a physiological record of all cases of eugenical sterilization under the several statutes.

STATISTICAL STUDIES OF STATE INSTITUTIONS.

The statistical study of State institutions for the defective, dependent, and delinquent classes which was planned by Dr. H. H. Laughlin, who, as special agent of the Bureau of the Census, had charge of the collection of the data, appeared in the year under review. This directory is important for the work of the Office, since we have extensive correspondence with State institutions and much of our field-work has hitherto been done in connection with them. The number of persons cared for in State institutions has a eugenical importance, since the basis of the defect which has made such State institutions necessary is largely hereditary. The total number of inmates of such State institutions in January 1916 was approximately 400,000, of whom half were in institutions for the insane, one-fourth in State institutions for criminalistic, about an eighth in State institutions for dependents, about 5 per cent in State institutions for the feeble-minded, and the rest in institutions for epileptics, tuberculosis, blind and deaf, and still other minor causes. The total expenditures by the States for maintenance and operation of these institutions was, in 1918, $81,000,000. The directory includes a number of summary tables for the United States, and then takes up for each State the general statistics for the State which bear upon its ability to care for defectives, and gives a list of the institutions in the State, together with a map showing the location of each. This is followed by a detailed statement for each individual institution, concerning its controlling body, its chief executive officer, the number of employees, income and expenditures, character of persons provided for, and the number of inmates.

STATISTICS OF ANCESTRAL INFLUENCE.

Work on mechanical devices for demonstrating the mathematical formulæ of heredity was continued by Dr. Laughlin. A machine was perfected for aiding the formulation of the mathematical aspects of the segregation and recombination of chromosomes in passing from generation to generation. Twenty-eight formulæ which present general mathematical pictures of hereditary processes were developed; these were described in a paper entitled "Calculating ancestral influence in man," read before the National Academy of Sciences at New Haven, Connecticut, November 10, 1919. Work on a series of calculations for formulating the mathematical aspects of the "Pure-sire system of breeding" and the "Measure of consanguinity" were begun and are progressing satisfactorily.

ARCHIVES.

The care of the archives has remained in the hands of Miss Louise Nelson. The following is a summary of material added to the archives, September 1, 1919, to September 1, 1920:

I. Index cards:	
1. Main index	68,167
2. Persons index	3,910
II. Manuscript material:	
1. Field reports	5,951
2. Miscellaneous	751
III. Special schedules:	
1. Record of family traits	351
2. Family distribution of personal traits	3
3. Twin	128
4. Weight	32
5. Eye, hair, and skin color	17
6. Other, including polydactylism, left-handedness, tuberculosis, deafness, etc.	59
IV. Miscellaneous material:	
1. Individual analysis cards	246
2. Genealogical data cards	157
3. Biographical data cards	150
4. Newspaper clippings:	
a. Biographical	27,048
b. Genealogical	7,600
V. Books:	
1. Biography	130
2. Collective biography	32
3. Genealogy	10
4. Town history	9
5. Miscellaneous pamphlets	76

Up to the present time there is a total of 752,231 cards in the Sextuple Index and 4,500 in the Persons Index. And since each card affords space for 40 entries, and, as some contain this number and many others as many as from 4 to 10, it is probable that there are more than 2,000,000 entries on file. Of the Record of Family Traits schedules there are over 3,500.

From the books received, 10,058 pages have been indexed, but because of lack of filers it has not been possible to add this material to the main card-index. In addition to this, 4,272 sheets containing 461,376 entries made from manuscript material have also been accumulated.

During the summer we were able to make use of the assistance of a number of college students, some of whom were doing other work at Cold Spring Harbor, in the preparation of material for the archives and in the analysis of the records. Mr. William Kraus assisted in the analy-

sis of weight. Miss Laura Craytor, Miss Ruth H. Twining, and Mr. Clyde E. Keeler, all of Denison University, assisted in the work of filing clippings of biographies, genealogies, and special traits.

TRAINING COURSE.

The 1920 training course for field-workers in eugenics was in session from June 30 to August 10. There were 13 students in the course. This brings the total number who have been trained by this Office for field-workers up to 205. Clinical instruction was received at the State hospitals for the insane at King's Park, Central Islip, and Ward's Island; also at Letchworth Village, Randall's Island, and at Brunswick Home (for feeble-minded) at Amityville. A clinic was also held by Dr. W. B. Weidler at the Manhattan Eye, Ear, and Throat Hospital, and another at the Hospital of the New York Society for the Relief of the Ruptured and Crippled. Opportunity was also offered for observing the physical examination of immigrants at Ellis Island.

JOINT-BASIS FIELD WORKERS.

During the year the Office has continued its practice of supplying custodial institutions with eugenical field-workers, training the worker and paying her salary, while the collaborating institution provides maintenance and expenses of travel. During the year Miss Virginia Rohde continued at the State Hospital at Bangor, Maine. Miss Cornelia Augenstein resigned from her appointment at the Girl's Training School at Gainesville, Texas, and Miss Mae C. Graham was appointed to succeed her. Our contract with the State hospital at Central Islip was completed by Miss Dorothy Aldridge. In view of limitations of income, it seems probable that we shall have to restrict for the present the number of joint-basis field-workers.

VOLUNTEER COLLABORATORS.

The archives of the Eugenics Record Office are being increasingly utilized by other institutions, as well as individual eugenicists, as a depository of records having eugenical significance. Many are institutions which became acquainted with the work of the office through the employment of trained field-workers, and have for some years contributed largely to the records of this office. Among these may be especially mentioned the State Village for Epileptics at Skillman, New Jersey (Dr. David F. Weeks, superintendent); Whittier State School, Whittier, California (Dr. Fred C. Nelles, superintendent); Minnesota School for Feeble-minded at Faribault, Minnesota (through Dr. F. Kuhlman, Director of Research); State Hospital at Middletown, Connecticut (Dr. Floyd C. Haviland, superintendent); Letchworth Village for Epileptics at Thiells, New York (Dr. Charles S. Little, superintendent).

Many teachers in our colleges and other educational institutions are introducing the study of family histories into their courses in genetics, sociology, biology, and psychology, and some of them contribute the results of the work of their students to the archives of this office. Among those who have especially made this Office the repository of such data may be mentioned: Professor Will S. Monroe, State Normal School, Montclair, New Jersey; Dr. Louis W. Rapeer, Washington, D. C.; Norman R. Stoll, Central High School and Junior College, Detroit, Michigan; H. R. Hubbard, Plainfield High School; Miss Gertrude Sevin, Adelphi College, Brooklyn, New York; Professor Donald W. K. Davis, College of William and Mary, Williamsburg, Virginia; Professor A. J. Goldfarb, College of the City of New York; Professor Robert A. Budington, Oberlin College, Oberlin, Ohio; Miss Elizabeth Whittaker, Elmira College; Professor Charles W. Hargitt, Syracuse University; and many others.

The office has also received from G. L. Meylan, Director of Physical Training of Columbia University, about 2,000 negatives showing the physical build of students of that institution.

Among personal workers who have contributed to the office the results of their studies are Dr. F. L. Reichert, of Johns Hopkins Hospital; Dr. Edward D. Churchill, of Faulkner Hospital, Jamaica Plain, Boston, Massachusetts; and Edward L. Caum, Honolulu, Hawaii, all members of former training classes.

THE SECOND INTERNATIONAL CONGRESS OF EUGENICS AND THE EUGENICS RESEARCH ASSOCIATION.

On March 20, 1920, a committee of the National Research Council on the Second Eugenics Congress met at Washington, under the chairmanship of your Director, and voted to hold such a congress in New York City, September 22 to 28 (inclusive), 1921. A meeting of the general committee on the congress was held at the American Museum of Natural History, New York City, April 10, 1920, Dr. R. S. Woodward presiding, and further details were elaborated. It is believed that this congress will have a very beneficial effect on the public attitude toward and interest in research in eugenics.

On January 9, 1920, the executive committee on the Eugenics Research Association, under the presidency of Dr. Stewart Paton, approved the personnel of the eugenics committee selected by the National Research Council. The secretary of the association appeared at a hearing of the Congressional Committee on Immigration, to present the eugenical aspects of immigration. The association also made arrangements by which it acquired control of the "Eugenical News."

The eighth annual meeting of the association was held at Cold Spring Harbor on June 25, 1920, under the presidency of Dr. Stewart Paton.

GEOPHYSICAL LABORATORY.[1]

ARTHUR L. DAY, DIRECTOR.

Throughout the war period the research problems upon which this Laboratory has been engaged since its establishment were all laid aside and our attention was concentrated upon the one problem of developing in this country an adequate source of supply of optical glass for the instruments of precision required by the Army and Navy for war purposes. Our responsibility included not only the development of methods and processes, the selection of raw material, and the manner of treatment of the product, but also included the factory control of manufacturing operations. This meant, of course, that most of the actual work was done in manufacturing plants more or less remote from Washington, so that not even a semblance of progress could be maintained in the direction of our regular scientific researches.

The particular war task to which we were assigned was also peculiar in that nothing of the kind had been seriously undertaken in this country before. It had been our habit to import the various kinds of optical glass required for instruments of precision, and we had become completely dependent upon foreign sources for this indispensable material. Such dependence carries with it obvious elements of danger in the event of war with a foreign nation and not inconsiderable limitations in time of peace, for there is not only commercial disadvantage but a lack of incentive in the development of new varieties of lens systems and in the other applications of optical glass if the entire product comes ready-made from abroad and even the limitations of manufacture are unknown. Many possible applications to the problems of peace as well as of war will remain undeveloped, and, in fact, have remained untouched in this country hitherto, because of this lack of acquaintance with the possibilities of development and application of special glasses. It will hardly be necessary to indicate in detail how helpless the nation is in event of war when all glass used in fire-control instruments is of foreign origin, and even the instruments themselves are largely of foreign design.

Not only did these limitations exist in acute form at the time when the United States entered the war in 1917, but substantially all the processes of manufacture of glass of this quality had been held secret in those countries where production had been most successful, either under the protection of Government monopoly or because of commercial expediency. In fact, not even the pressure of war proved adequate to break down this wall of secrecy and bring to our shores in our moment of need the technical information necessary to enable us to take up at once the manufacture of successful glass.

[1]Situated in Washington, District of Columbia.

This was the situation which the Laboratory confronted in 1917, and for which it was required to find a solution in the shortest possible time. The success attained is now a matter of record in previous annual reports of this department and need not be adverted to here; but our task was not complete with the delivery to the Government of the glass which it needed for war purposes. It remains for us to safeguard the nation, so far as it may lie in our power to do so, against the consequences of another such danger in case it should arise. It has accordingly appeared to be our plain duty to tear aside the mask of secrecy which has hitherto surrounded optical-glass manufacture and, to the extent that our experience has made it possible, to leave such a record that our successors may have the information necessary to make these glasses at some future time if they are needed. Whether this demand may find its origin in peace-time developments—that is, in the requirements of research, of engineering, and of commerce and for instruments of precision—or in the need for fire-control instruments for national protection, need not concern us now.

In pursuit of this plan, about twenty papers were prepared and published during the year 1919 (see the report of the Acting Director of the Geophysical Laboratory for 1919, Year Book 18, p. 153), containing the record of the experience of the members of the Laboratory staff with the various processes of optical-glass making. During the year just passed ten more were issued (of which brief reviews will be found in the following pages); that is, about one-third of the total published work of the Laboratory for the year was again given up to the same purpose, and still other papers are in preparation. Indeed, it is the purpose of the Laboratory to leave as complete a detailed record of these activities as practicable. When these publications are completed and eventually issued in permanent form, the connection of the Laboratory with optical-glass development as a manufacturing process will cease. No attempt was made to reproduce all the known forms of optical glass, nor to extend the bounds of existing knowledge of glass-making in any particular direction, but enough was accomplished to supply the nation in its time of greatest need and to insure it against another such crisis in the near future. Beyond this it was not deemed to be our duty to go, if indeed the limited time at our disposal had permitted us to do so.

Quite a new method of studying the intimate structure of matter became available in 1913 through the discovery that X-rays suffer a change in direction—a diffraction—when they are passed through crystals. For instance, if a narrow pencil of the rays passes through a thin section of a single crystal, a diffraction pattern will be obtained which is characteristic of the particular crystal and is presumably conditioned by the arrangement of the atoms of which it is composed. Upon this observation as a basis, the British physicisists, W. H. and W. L. Bragg, were enabled to place the atoms in a few simple crystals.

The usefulness of these observations is obviously great, because a knowledge of the exact location of the atoms in a body makes possible not only some sort of an intelligent discussion of the manner in which they are bound together, but also should serve as a basis upon which to build quantitative measurements of the forces operating within solid bodies. When combined with other information which seems to bear upon the nature of the forces of chemical combination, a knowledge of the crystal structure of a compound may not only indicate the probable way in which the atoms are related chemically to one another, but may even tell something of the internal structure of the atom itself. To illustrate, it was shown, in the course of studying the members of the calcite group of minerals, that the oxygen and carbon atoms in these carbonates are always associated together in exactly the same way, even though the relations of these atoms to the others present differ from one compound to another, thus pointing quite clearly to the existence of definite groups of atoms in the solid crystal. At the same time it became evident that on the basis of our present knowledge it is quite impossible for the outside electrons of these atoms to be arranged at the corners of cubes, as some have assumed to be the case with all atoms.

Again, an attempt to explain quantitatively the diffraction of X-rays leads immediately to the formulation of definite hypotheses as to the entire internal structure of the atom and gives a criterion whereby their probable correctness may be gaged.

These earlier methods of study are applicable only to the simplest of bodies. It consequently has been necessary to attempt to develop a way of investigating the structure of crystals which would be capable of application to the more complicated, but more interesting and important, substances. A brief outline of such a method and its application to two rather simple crystals has been given in recent publications from this Laboratory. A more detailed discussion of this subject will, it is hoped, appear shortly as a book.

Diffraction effects of this sort can be obtained not only from individual crystals, but as well from any material in which the atoms stand in a regular relation to one another. We, therefore, have offered to us the possibility, and it is yet for the most part only a possibility, of studying the intimate structure not only of crystalline powders and little understood "liquid crystals," but even of some liquids. Many interesting questions thus present themselves; for instance, do the atoms within the molecules of complicated organic substances bear definite spacial relationships to one another even in the liquid state? are the individual particles of a colloidal suspension made up of a definite and orderly or of a haphazard grouping of atoms? what happens to the intimate structure of a compound when it takes another substance into solid solution with itself? is a particular rock substance, the hydrated silicate of copper, chrysocolla, for example, or

even the opal, really made up of a myriad of minute crystalline particles, or is it truly amorphous?

The fact that every chemical individual is characterized by its own particular effect upon X-rays likewise furnishes us with a method which should serve as a considerable aid to the microscopic methods for the identification of particular rock-making materials.

Three definite methods have been developed for these investigations of crystalline materials. One of them is based on the original experiments of Laue with transmitted radiation and has thus far been the one most used in this Laboratory; another, wherein the X-rays are "reflected" from particular faces of the crystal, has been developed by W. H. and W. L. Bragg; the third comprises the various ways of studying powders and similar material. These three methods have never been used together, nor carefully contrasted with one another to determine their particular fields of usefulness. This Laboratory has been engaged in installing the apparatus necessary for such a critical study and joint use as will result in a more systematic manner of treatment of the problem of studying the structure of crystals. It promises to afford a new mode of attack on the great problem of rock formation, different from any other and of great possible usefulness.

During the summer a congress of scientists was held in Honolulu, Hawaiian Islands, to discuss for the first time the specific scientific problems offered by the Pacific Ocean and adjacent land areas. The Congress was called together by the director of the Bishop Museum of Honolulu, and an invitation was extended to this Laboratory to be represented by a delegate who might participate in the discussions on volcanology. A few paragraphs from the report of Dr. H. S. Washington, who represented this Laboratory and the American Geophysical Union, will give a brief outline of the purpose and results of the Congress.

"October 13, 1920.

"I have the honor to make the following brief report on the activities of the 'Pan-Pacific Scientific Congress,' held at Honolulu, August 2 to 20, 1920, which I attended as a delegate from this Laboratory and from the American Geophysical Union.

"The number of delegates present was 111, representing Australia, New Zealand, Tahiti, the Philippines, Canada, England, Japan, China, and the United States, these last being almost equally divided between the Hawaiian Islands and the mainland. The sciences represented by the delegates were anthropology, astronomy, biology, botany, chemistry, entomology, ethnology, geodetics, geography, geology, meteorology, oceanography, seismology, volcanology, and zoology.

"After the opening and organization, Herbert E. Gregory being chairman, the activities of the Congress were divided into the following sections: anthropology, biology, botany, entomology, geography, geology, seismology, and volcanology. General joint meetings were held daily, as well as meetings of the separate sections, except for the second week, which was devoted to a visit of the Congress to Hawaii and Kilauea.

"The general purpose of the Congress was to promote cooperative study of the scientific problems of the Pacific region by the countries bordering on or occupying islands in it. The general procedure followed in the discussions was thus outlined by Professor Gregory:

"1. What has been accomplished in the scientific study of the Pacific?

"2. What is there to be done, and what is of most importance?

"3 What are the best means of completing our scientific study of the Pacific?

"All the meetings were well attended, the public of Honolulu being well represented at the general meetings; the discussions were animated and earnest, and in general the whole atmosphere of the Congress was one of serious endeavor to accomplish the objects of the meeting and a full recognition of their importance. It may be added that the attitude of the people of the Hawaiian Islands, official and private, was one of great interest in the Congress and of the utmost cordiality and hospitality.

"The Congress closed with the adoption (in general meeting) of a series of recommendations and resolutions which embodied the results of the various sectional discussions as to the most important problems and the best means of procedure in accomplishing the general object of cooperative study of the Pacific by the countries interested. These resolutions and recommendations are too numerous and lengthy for presentation in detail here. I may, however, give a very brief résumé of their general tenor and of some of the more important of them.

"The meetings of the first Pan-Pacific Congress having demonstrated the value of such conferences, it is strongly recommended that a permanent organization be formed, and that the conferences be continued in the future at regular intervals. It is recommended that such an organization be affiliated with the International Research Council and the various National Research Councils of the nations of the Pacific. It was the general sense of the delegates, though not embodied in the resolutions passed, that Honolulu is the most appropriate place for a central clearing-house or for the localization of general activities, being the most centrally situated large city, easy of access from all Pacific ports, and with the facilities of the Bishop Museum. The attention of governments is called to the advisability of providing vessels for suitably planned expeditions, and the promotion of general education in Pacific matters is urged, with the establishment of suitable fellowships.

"In anthropology, the urgent need of the immediate prosecution of Polynesian research along various lines is pointed out and the Dominick expedition is commended.

"In biology, a systematic marine biological survey is recommended, and the importance of an immediate and intensive study of Polynesian land fauna and flora is urged.

"In geography, the inadequacy of existing maps and charts is pointed out, and the making of proper surveys, especially of shorelines, coastal waters, and ocean-floor topography, is recommended, as well as oceanographical studies. The importance of the study of Pacific meteorology is emphasized and the establishment of meteorological stations on Macquarie Island and on Mauna Loa is recommended.

"In geology, special stress is laid on the importance of the making of proper geological maps of the Pacific region and the general study of Pacific geology, it being specially recommended that geological surveys be made of Easter Island, the Hawaiian Islands, and the Fiji Islands; that the configuration of the floor of the Pacific, the stratigraphic correlation of post-Cretaceous formations of the Pacific, and the study of sedimentary processes and rocks be undertaken.

"In seismology and volcanology the importance of volcano stations is

pointed out, and the continuance of present volcano and earthquake observatories and the establishment of new ones are strongly recommended, with proper publication of the results obtained. Several minor points are emphasized, such as collection of volcano and earthquake statistics, the collection of volcanic rocks, the establishment of a central bureau for the prompt and efficient dissemination of seismological and volcanological information, and the proper education of dwellers in districts liable to seismic or volcanic disaster.

"It is intended to issue officially a brief statement of the recommendations in the immediate future, with a later publication of the full proceedings and various papers, chiefly on Pacific topics, presented at the meetings or contributed by delegates."

During the summer of 1919, one of the expeditions of the National Geographic Society to Mount Katmai in Alaska gave opportunity for the continuation of our volcano studies in an entirely new field. The last eruption of Katmai occurred in the summer of 1912 and was characterized by explosions of such volume and intensity that ashes from the eruption reached the higher levels of the atmosphere much in the same manner as in the case of the well-known Krakatoa eruption in 1883.

In general, it is not possible to approach volcanic phenomena of such extreme violence for the purpose of making collections of material for laboratory study. The student is necessarily dependent upon such collections as he can make long afterward, and some of these suffer from the disadvantage that it is not possible to be fully assured that chemical or physical modification has not occurred between the period of eruption and the time of collection. In the case of Katmai this situation is further aggravated by the large annual rainfall and by the location of the volcano, which is remote from the ordinary routes of travel. It is also difficult of overland approach, and the summer season in which field studies are practicable is very short.

Notwithstanding these limitations, the National Geographic Society has sent several expeditions into the region, originally for the purpose of studying the subject of revegetation of an area completely devastated by volcanic activity, and later of somewhat broader scope to include geological and geophysical phenomena connected with the eruption itself. These later studies may have been suggested by the discovery of a very unusual and conspicuous phenomenon observed there, which appears to have persisted without noticeable diminution since the close of eruptive activity. There is an area to the northwest of the volcano which, for the number of active fumaroles, the volume of gas ejected, and the generally high fumarole temperatures, is probably not equaled elsewhere in the world at the present time. The leader of the expedition, Professor Griggs, has very graphically pictured its character by naming it "The Valley of Ten Thousand Smokes." Apparently this fumarolic action has lost little of its intensity since the close of the period of maximum volcanic activity and still offers the

best opportunity now existing for the study of this particular form of subordinate volcanic disturbance.

Through the courtesy of the National Geographic Society, the Geophysical Laboratory was permitted to send three members of its own staff to make studies of the chemistry and physics of the fumarole region and of the general geologic relations in so much of the region surrounding the volcano as might be covered in one short Arctic summer. This amounted altogether to a little more than two months. Every courtesy was shown by the Society and every facility given which the rather strenuous conditions of life in so remote and so desolate a region permitted.

Many of the fumarole temperatures were measured. It proved possible to collect samples of the gas from some, as well as quantities of incrusted salts. On account of the rather overwhelming amount of rain in this region in the summer season, favorable conditions for the accumulation of water-soluble salts seldom occur, but in general the efforts to obtain characteristic material were fairly successful. It also proved practicable to visit Katmai crater, to make a study of the characteristics of the eruption as revealed in the deposits of ejected material, and to obtain extensive collections of the solid ejecta for laboratory study.

It may be said that by far the largest portion of the gaseous matter emanating from the fumaroles at the time of this visit was water-vapor. Little evidence was found of the presence of explosive gases such as commonly characterize the violent stage of an explosive volcano, though chemically active gases (H_2S, HCl, HF) are still present in the fumaroles in small quantity. One must not be overhasty, however, in adopting the simple assumption that the great field of fumaroles is merely the result of a heavy deposit of hot ash or other ejectamenta, accumulated in an extensive drainage basin and gradually cooling there. To the experienced eye of the geologist the location of the fumaroles, remote and apparently quite separated from the center of activity, together with the character of the deposit through which the gases have emerged, plainly indicates that this is not a simple case of cooling of a great mass of débris kept more or less continuously saturated by atmospheric precipitation. Moreover, a number of the fumaroles are found on the hillsides above the valley and have no present relation with the deposit of débris. That such a mass, amounting in all to something like a cubic mile, should find its way from the main vent to a single distant valley without invading neighboring or intervening territory is in fact quite unthinkable.

From observation nothing is directly known either of the time (save only that it is overlaid by the ash) or the manner in which this deposit was laid down, but it is certainly true that new matter, to the depth of 100 feet or more in places, has appeared in

the valley which was not there before the outbreak took place. It is, however, clear from a study of the terrane that this material did not find its way from the main vent to its present location, either through the air or by any form of flow. The only conclusion, therefore, appears to be that the bottom of the valley itself must have been fractured and that the major portion of the material now found must have been forced up through one or more openings in the valley floor. Dr. Fenner's observations also indicate that the material must have advanced through the valley while still hot enough to consume trees, and must therefore have been a dry flow rather than a mud flow, perhaps with something of the physical texture of dry sand more or less charged with gas and loaded with coarser fragments and pumice. It possesses none of the characteristics of a fluid or semi-fluid lava stream.

Similarly, the origin of the fumaroles has been a matter of some doubt; neither their gas-content nor their wide distribution had at first suggested that they could be the result of primary activity. On the other hand, if they are secondary, their long duration indicates a very unusual supply of heat from an, as yet, undetermined source. The valley is obviously the drainage-basin for a mountainous area in which the rainfall is very large and the prevailing temperature throughout the year is low. There is no essential difficulty in accounting for the water-content of the fumaroles, but it may fairly be presumed that so extensive a fumarole area, persisting with practically undiminished intensity for a period of eight years, would require a very much greater or more intense source of heat than would be afforded by cooling ejecta, even in great mass. These apparent anomalies contribute to the problem very unusual features compared with any other fumarole area known to geologists, and the results of the intensive studies now being made in the laboratory of all the material collected there, both gases and solids, will be awaited with unusual interest.

Brief reviews of the papers published by members of the Laboratory staff during the current year follow:

PUBLICATIONS.

(1) The term "inversion." J. B. Ferguson. Science, 50, 544–546 (1919).

The diversity among the phenomena which are referred to by the name "inversion" is so great that at present the word has lost any precise meaning which it may have had in the past. In this paper the suggestion is made that inorganic chemists confine the word *inversion* to solid single-phase phenomena, such as the change of rhombic to monoclinic sulphur, and the term *transition* to phenomena such as an incongruent melting, instead of the present synonymous use of these terms for all these phenomena.

(2) Polarized light in the study of ores and metals. Fred. E. Wright. Proc. Am. Phil. Soc., 58, 401–447 (1919).

In this paper the attempt has been made to present in connected form the electromagnetic theory of the reflection of light from absorbing media, and

especially that part of the theory which treats of the reflection phenomena resulting from vertically incident light-waves under the conditions usually encountered in the use of the reflecting or metallographic microscope. Normally incident white light contains, after reflection by an anisotropic substance, a certain amount of plane-polarized light, and this amount increases with the strength of the birefringence and the biabsorption in the crystal plate. The presence of plane-polarized light in natural light can be detected by several different methods, such as are used in determinations of sky polarization. For this purpose Koenigsberger adopted the Savart method with rotating glass compensator. A second and new method is proposed which employs either a single calcite cleavage plate with proper aperture or a small portable Koenig-Martens photometer. This method is more sensitive than the first. Methods of this kind, which are based on differences in intensity of the reflected components of vertically incident light, are fifty or more times less sensitive in the detection of anisotropism than methods based on the phenomena produced by plane-polarized transmitted light-waves.

In case vertically incident, plane-polarized light is used, the difference in amplitude of the reflected components causes a rotation of a plane of polarization, and this can be detected and measured by any one of a number of devices in common use by petrologists, such as the sensitive-tint quartz plate, the Biot-Soleil sensitive-tint biplate, the Bertrand eyepiece, and the biquartz-wedge plate. Of these, the last is the most sensitive, because in it the sensibility is variable and can be adjusted to meet the conditions of illumination.

In opaque substances the precision attainable by these methods is, in general, small, and the phenomena which can be observed are relative few and restricted in scope. As a result, one can not expect from the application of polarized light to such substances the harvest of optical data which has been gathered from transparent crystals.

(3) The measurement of the intensity of transmitted and reflected light by polarization photometers. Fred. E. Wright. J. Opt. Soc. Amer., 2, 65–75 (1919). (Papers on Optical Glass, No. 22*a*.)

In this article a brief statement is given of the methods used by the writer during the war period for the measurement of the light transmission of optical glasses and of optical instruments. Several new attachments and improvements on the Koenig-Martens photometer are described; also the method for their use in the practical measurement of the amount of light transmitted and reflected by optical glasses, and of the light transmission of optical instruments.

(4) Polarization photometer prisms. Fred. E. Wright. J. Opt. Soc. Amer., 2, 93–96 (1919). (Papers on Optical Glass, No. 22*b*.)

In this paper is considered the quantitative effect of external and internal reflections on the intensity of light-waves transmitted by the calcite rhomb and the Wollaston prism, when these are used in photometric work. This discussion is necessary to an adequate understanding of polarization photometers and the factors underlying their use.

(5) The contrast sensibility of the eye as a factor in the resolving power of the microscope. Fred. E. Wright. J. Opt. Soc. Amer., 2, 101–107 (1919).

In this paper three factors of importance in high-power microscope work are emphasized, namely: (*a*) The use of a polarizing prism to eliminate that part of the field-light which does not contribute to the diffraction pattern in the image and hence tends to reduce the contrast and to decrease the sharpness and crispness of the image. This phenomenon arises because diffracted beams, which emerge from gratings whose interval is of the order of magnitude

of half a wave-length of light, are sensibly polarized in a plane normal to the lines of the grating. (*b*) A diaphragm of the rectangular type, for use in the image plane of the eyepiece in order to cut out all light except that from the particular object under examination. The field should, however, cover at least 10°. (*c*) The importance of a field intensity of illumination approaching that of day-light and best adapted for the eye at any particular time. The simplest method for securing this is by means of a substage polarizer in conjunction with the polarizing prism; the polarizer can be rotated, and with it the intensity of illumination of the field varied. These factors are not important for ordinary observations, because the resolving power there required is not great; but in high-power, critical work they are significant and enable the observer to accomplish with comparative ease that which under other conditions is a matter of difficulty.

(6) Examination of ores and metals in polarized light. Fred. E. Wright. Mining and Met., No. 158, Sect. 9 (1920).

A discusssion is given in this paper of the different methods which may be used in the determination of opaque minerals by the effect which they have on vertically incident light-waves, either non-polarized or polarized. On reflection from a birefracting, biasorbing crystal plate, such waves are modified to some extent, and these changes can be recognized and measured with suitable apparatus.

A description of these instruments and of the several factors underlying their use is given. Several new methods are suggested which have proved to be satisfactory in practice.

(7) A trigonometric computer. Fred. E. Wright. J. Wash. Acad. Sci., 10, 29–31 (1920).

The trigonometric computer described in this paper was devised and constructed in the Geophysical Laboratory for the purpose of computing the angles in oblique spherical triangles with a degree of precision about one-half minute of arc. This instrument has been in use since 1913; it enables the observer to save an appreciable amount of time in computing the angles of a spherical triangle which otherwise would have to be done by logarithms.

(8) A graphical method for plotting reciprocals. Fred E. Wright. J. Wash. Acad. Sci., 10, 185–188 (1920).

In the search for a mathematical function which shall represent satisfactorily the data obtained from a series of experiments, it is convenient in certain instances to plot the reciprocals of one of the variables and from the curve thus obtained to deduce the form of the desired equation. In this paper a simple method for accomplishing this purpose is described and the principle explained on which the method is based.

(9) Estimating impurities by means of the melting-point curve. Walter P. White. J. Phys. Chem., 24, 393–416 (1920).

Freezing-points where the thermometer is immersed in the substance are more reliable and precise than those by the capillary-tube method. If, in addition, the form of the freezing curve is observed, there is obtained an indication of the amount of impurity which is independent of all previous knowledge or uncertainty as to the melting-point of the pure substance, and even of the absolute accuracy of the observer's thermometer. If the determinations are a control of a purification process, there are also a saving of time and the avoidance of certain serious chances of error.

Smallness of dimensions diminishes local temperature differences and is very often a superior substitute for stirring of the tested substance. It also economizes both time and material. A small thermo-couple or thermel of several couples lends itself very well to use in small test samples.

The complications, usually almost negligible, arising from specific heat, uneven temperature, and other causes are considered, and suitable experimental arrangements are suggested.

(10) A practical test for the resistance of optical glass to weathering. F. Russell v. Bichowsky. J. Am. Ceramic Soc., 3, 296–304 (1920). (Papers on Optical Glass, No. 23*a*.)

The experiments described in this paper were made in 1917 with the object of getting a rapid routine method for testing the weather stability of the optical glasses then being made for military purposes. There was no opportunity to make long-time tests under conditions to be met in the field, although such tests should underlie any future exhaustive investigation to correlate weathering resistance with routine laboratory tests.

The surface-alkali test described by Mylius was used, but its indications are not certain for all types of glasses. Methods of determining the rate of solubility in water, ammonia, or hydrochloric acid were also tried, but were not found adaptable for routine procedures. The tests finally adopted consisted in heating samples of the glass, in company with a standard glass, in water, 5 per cent sodium hydroxide, and 1 : 1 hydrochloric acid, at temperatures of 175° or 225° C. The glasses could then be classified into 9 groups according to their appearance when wet and when dry, although there is sometimes considerable difference in the order of stability found with the three reagents used. The safest estimate is one based on the three tests taken as a group.

The results of these tests were compared with the results by the surface-alkali and rate-of-solubility methods.

(11) Note on the mechanics of the "weathering" of glass. F. Russell v. Bichowsky. J. Am. Ceramic Soc., 3, 309–312 (1920). (Papers on Optical Glass, No. 23*b*.)

The mechanism of the weathering of a glass surface by water is believed to consist in the following stages: (1) True adsorption; (2) diffusion of adsorbed water into the glass; (3) reaction with the silicates; (4) soaking-up of more water by the film so produced; (5) extraction of the soluble salts; (6) solution of the silica skeleton. The appearance and behavior on heating of glasses in each of these stages are described.

(12) Chemical researches on sediments. Herbert E. Merwin. Bull. Geol. Soc. Amer., 31, 419–424 (1920).

The purpose of this paper is to discuss in a general way various phases of the chemical problems connected with the study of sedimentary rocks. The problems in general are difficult because of the complexity of the solutions, the slight solubility and the lack of definite crystallinity of many of the substances, and the persistence of unstable phases.

Diffusion in the solid state, consolidation under differential stress, adsorption, slow reactions, and effects of catalysis are discussed both in general and with respect to such problems as the formation of dolomite and phosphate rocks, and the oceanic red clay.

(13) The manufacture and uses of rolled optical glass. H. S. Roberts and J. C. Hostetter. J. Am. Ceramic Soc., 3, 750–761 (1920). (Papers on Optical Glass, No. 24.)

Rolled optical glass is manufactured by a process that combines the stirring and earlier processes used for ordinary optical glass with the casting and subsequent processes ordinarily used in the manufacture of rolled plate-glass. The glass obtained is characterized by the presence of striæ in the form of plane-parallel films, which are in general invisible unless viewed edgewise. Optical systems manufactured from rolled glass should therefore be so de-

signed that the path of light-rays cuts the striations in a direction that is as nearly as possible normal to the direction of the striations themselves.

The methods of manufacture and inspection are described and a discussion given of the manner of forming the glass into blanks for prisms and lenses.

This method lends itself admirably to large-scale manufacture of glass suitable for most of the optical instruments used in warfare, for photographic lenses, field-glasses, spectacles, and low-precision instruments in general. For instruments of the highest precision, recourse must still be had to the older process of cooling the glass in the pot.

(14) Note on the motion of the stirrers used in optical-glass manufacture. E. D. Williamson and L. H. Adams. J. Am. Ceramic Soc., 3, 671–677 (1920). (Papers on Optical Glass, No. 25.)

Perhaps the most noticeable difference between the manufacture of optical glass and that of other types of glass (bottle, window, and plate) is that the melt must be stirred vigorously in order to get complete mixing. The reason behind this necessity is the close approach to homogeneity specified in the tests to be passed by the finished article.

The stirrers used are necessarily of a very simple nature, generally consisting of a clay rod attached at right angles to an iron water-cooled pole, the other end of which is driven at steady speed in a horizontal circle, while supported near the center by a pulley or other support. Such a device does not cause circular motion of the stirring-rod, but causes it to describe an egg-shaped figure at a variable speed. A slightly more uniform motion is obtained if a pin attached to the pole slides in a fixed slot instead of the pole passing over the pulley, but the general results are not very different. If the support is not close to the center of the pole, the motion of the rod is far from circular and a large part of the glass in the pot is not stirred.

(15) Italite: a new leucite rock. Henry S. Washington. J. Wash. Acad. Sci., 10, 270–272 (1920).

A brief statement of the article reviewed under No. 16 below.

(16) Italite: a new leucite rock. Henry S. Washington. Am. J. Sci., 50, 33–47 (1920).

This very exceptional rock is represented by a small specimen from a flow on the west slope of the volcano of Rocca Monfina, north of Naples, where it was collected by Baron Dr. G. A. Blanc and Ing. F. Jourdain, of Rome, who kindly gave the specimen and permitted the publication of the results of its study.

The rock is rather coarse-grained and friable, composed almost entirely (90 per cent) of leucite crystals, 3 to 5 mm., that show the twinning structure remarkably well, with small amounts of ægirite-augite and a titaniferous garnet, and a little interstitial colorless glass base, which is probably composed in great part of uncrystallized noselite and melilite. The presence of glass and the microstructure show that the rock is from a flow, and is not a tuff.

The chemical analysis gave:

SiO_2	51.02	K_2O	17.94	P_2O_5	0.02
Al_2O_3	22.21	H_2O+	0.82	SO_3	0.76
Fe_2O_3	1.48	H_2O-	0.11	Cl	0.08
FeO	0.57	CO_2	none	$(Ce, Y)_2O_3$	trace
MgO	0.14	TiO_2	0.57	MnO	0.01
CaO	2.31	ZrO_2	0.06	BaO	0.20
Na_2O	1.67				
					99.97

This analysis is extremely remarkable, especially in the high percentage of K_2O, which is far above that of any other known rock, the next highest figure being only 11.91.

In the quantitative classification the rock falls in the as yet unrepresented position I.9.1.1, and the name *italite* is given it in the current classification, the name leucitite being already in use.

Chemical analysis (made on 0.0639 gram) of the garnet showed that it is a titanium-rich andradite, like those of other Italian lavas. The very high refractive index (1.94) is analogous to those of other titanium-rich garnets, whose refractive indexes were also determined by Dr. Merwin, of this Laboratory.

(17) Sull' italite: un nuovo tipo di roccia leucitica. Henry S. Washington. Atti Accad. Lincei, 29, 424–435 (1920).

An Italian translation of "Italite: a new leucite rock" (Amer. J. Sci., 50, 33–47, 1920). Reviewed under No. 16 above.

(18) Dispersion in optical glasses: I. Fred. E. Wright. J. Opt. Soc. Amer., 4, 148–159 (1920). (Papers on Optical Glass, No. 27.)

A convenient graphical method for illustrating the relations between different types of optical glasses is to plot for each glass its refractive index, n_D, against the ratio $\frac{n_D - n_{A'}}{n_{G'} - n_F}$.

If partial dispersions alone are considered and plotted one against the other, the result in each case for a series of optical glasses is a straight line. This fact, that in a series of optical glasses the partial dispersions are related by linear functions and that these functions are the same for all glasses, proves that, if a single partial dispersion is given, the entire dispersion-curve is fixed, irrespective of the type of glass. This means that within the limits to which this statement holds, namely, about one unit in the fourth decimal place, if any partial dispersion is given, all other dispersions follow automatically. Thus, a series of standard dispersion-curves can be set up independent of the absolute refractive index. This means that if for any substance two refractive indices be given, the dispersion-curve can be written down directly; that in case two substances of very different refractive indices are found to have the same actual dispersion for one part of the spectrum, their dispersion curves are identical to one or two units in the fourth decimal place throughout the visible spectrum. From these relations it is possible to build up dispersion formulas containing two, three, or more constants which represent the data in the visible spectrum with a high degree of exactness. Certain of these formulas are of such form that they are valid far into the infra-red and ultraviolet, but break down of necessity as an absorption band is approached. Certain of the dispersion formulas thus obtained are well adapted for computation purposes.

(19) Dispersion in optical glasses: II. Fred. E. Wright. J. Opt. Soc. Amer., 4, 195–204 (1920). (Papers on Optical Glass, No. 29.)

In this paper proof is given that, because of the relatively short range of the visible spectrum, the substitution in a dispersion formula of the reciprocal of the refractive index, or of the excess refractivity, or by analogy of other functions of the refractive index for the direct values, leads to dispersion formulas which are fairly satisfactory. Thus, if in the two-constant Cauchy formula, $n = A + B \cdot \lambda^{-2}$ or $n - 1 = A' + B \cdot \lambda^{-2}$, the reciprocal of the refractive index or of the excess refractivity be written: $n^{-1} = C' + D \cdot \lambda^{-2}$ or $(n-1)^{-1} = C + D \cdot \lambda^{-2}$, the new equations represent rectangular hyperbolas in case λ^{-2} is considered to be the independent variable. The last equation was recently suggested as a substitute for the Hartmann dispersion formula. A series of computations demonstrates, however, that for the crown-glasses this equation is less satisfactory than the Cauchy formula, while for the flint-glasses none of

the foregoing equations is especially good. The last equation is, moreover, always less satisfactory than the Cauchy formula for computation purposes. The usefulness of the last equation appears, therefore, to be limited and less satisfactory for general application than the two-constant Cauchy formula.

(20) Classification and nomenclature of optical glass. George W. Morey. J. Opt. Soc. Amer., 4, 205–212 (1920). (Papers on Optical Glass, No. 28.)

The independent development of the optical-glass industry in different countries and by different manufacturers, during the course of which each manufacturer listed new glasses as they were developed under whatever names seemed appropriate, has resulted in great confusion in nomenclature—a confusion increased by a frequent lack of consistency on the part of individual manufacturers. It was the purpose of the author to simplify the nomenclature of optical glass by the elimination of many of the special names, retaining only those which, while indicating the position of the glass in the general scheme, leave the precise specification to be made by means of the optical properties.

The system of optical-glass nomenclature proposed is based on the crown-flint series of "older" glasses, *i. e.*, barium-free glasses. The dividing-line between crowns and flints is at a ν-value of 56, the approximate lower limit of the lead-glasses. The crowns are divided into fluor crowns, with ν-value greater than 68; borosilicate crowns, with ν between 68 and 61; and ordinary crowns, with ν from 61 to 56. The flints are divided into extra light, ν from 56 to 50; light flints, ν from 50 to 38; medium flints, ν from 38 to 34; dense flints, ν from 34 to 31; and extra dense flints. Glasses falling outside the crown-flint series are grouped with the barium-crowns and barium-flints. The barium-crowns have n_D higher than 1.60, the light barium-crowns have n_D between 1.60 and 1.54. The barium-flints are divided into light barium-flints, n_D less than 1.60; medium barium-flints, index between 1.60 and 1.64; and dense barium-flints.

It is emphasized that optical-glass type names are for convenience in casual reference only, and do not imply a specification of optical properties. Whenever reference is made to a definite glass, as opposed to the broad general type, whether in the purchase of glass or in discussion of properties or uses, the reference should be made exact by specifying the optical properties, usually the refractive index for sodium light and the ν-value.

(21) The binary system åkermanite-gehlenite. J. B. Ferguson and A. F. Buddington. Am. J. Sci., 50, 131–140 (1920).

The binary system åkermanite ($2CaO.MgO.2SiO_2$)-gehlenite ($2CaO.Al_2O_3.SiO_2$) was studied by the quenching method and the solidus and liquidus curves were determined. The system forms a complete series of solid solutions with a minimum melting-point about 70° below the melting-point of åkermanite, the component of lower melting-point, at a composition of about 74 per cent åkermanite and 26 per cent gehlenite.

The densities of crystals and glasses of åkermanite, gehlenite, and several intermediate mixtures were determined and found to confirm the isomorphous character of the system. Åkermanite was found to show the unusual feature of its glass having a greater density than the corresponding crystals at 25° C. This peculiar character is checked by the indices of refraction for glass and crystal respectively, the index of refraction of the glass being greater than the maximum index of the crystal.

The optical characters of the crystals are a continuous function of the composition. In optical characters åkermanite is positive and gehlenite is negative. Crystals of certain intermediate compositions are isotropic for

light of a definite wave-length and constitute a transition phase between positive and negative crystals.

Vogt has discussed the relations of åkermanite and gehlenite as interpreted from a study of slags. He concluded that they mix to form an isomorphous series and found that the birefringence of intermediate mixtures decreases to zero. However, the formulas assumed by Vogt for åkermanite and gehlenite differ from those used by us, and most of his materials contained iron, manganese, soda, or other impurities, so that the data he obtained are the result of more complex mixtures than the system discussed by us.

(22) A note on the annealing of optical glass. L. H. Adams and E. D. Williamson. J. Opt. Soc. Amer., 4, 213–223 (1920). (Papers on Optical Glass, No. 30.)

This paper discusses the origin of internal strain in glass and its removal, and specific directions for the practical annealing of optical glass are given. The subject of annealing is treated more fully in another paper ("The Annealing of Glass").

(23) Optical properties of anthophyllite. N. L. Bowen. J. Wash. Acad. Sci., 10, 411–414 (1920).

The refractive indices of anthophyllite from Franklin, Macon County, North Carolina, are redetermined and found to be as follows:

$$\gamma = 1.6404 \qquad \beta = 1.6301 \qquad \alpha = 1.6195.$$

These values are found to be in complete accord with those for anthophyllite from Kongsberg and the pure artificial amphibole $MgSiO_3$ when the $FeSiO_3$ content is plotted against refractive indices.

(24) The rhyolites of Lipari. Henry S. Washington. Am. J. Sci., 50, 446–462 (1920).

Typical obsidians, pumice, lithoidal rhyolite, and a hyalo-dacite of Lipari are described, with six new analyses. As these rhyolites are regarded as typical and have never before been properly analyzed, this work is of use in characterizing the type. The refractive indices of the obsidians and pumice, determined by Dr. Merwin, are discussed. There is also given an analysis of an obsidian of the island of Milos, of which the refractive index was also determined. The data correspond well. This is compared with analyses of obsidian of Nisyros by Martelli.

The observation is made that ferrous oxide dominates ferric oxide in the glassy forms of the same magna, while the converse is true of the crystalline forms in the Lipari rhyolites. The same holds good for the rhyolites of Sardinia and the pantellerites and basalts of Pantelleria, described some years ago by the writer. The possible relation of this to the magmatic gases in lavas is briefly discussed.

(25) Certain relations between chemical composition and refractivity in optical glasses. Fred. E. Wright. J. Am. Ceramic Soc., 3, 783–832 (1920). (Papers on Optical Glass, No. 31.)

The manufacture of optical glass as a war-time problem required the solution of many different phases in order to establish it on a definite basis of routine quantity production. One of these problems was the development of suitable batches for the several types of optical glasses needed in military optical instruments. This necessitated a detailed study of the relations between chemical compositions and optical constants of glasses and of the factors, such as volatilization, pot solution, and state of annealing, which tend to change the relations during the manufacture of the glass. The amount of accurate information available at the time, especially of a chemical nature, was meager but exceedingly valuable. The problem was accordingly attacked by graphi-

cal methods and solved sufficiently to enable us to write down approximately correct batches for the types of glass which were urgently required. A few experimental melts then made it possible to correct for errors arising from selective volatilization and the like, and thus to set up satisfactory batch compositions.

In this paper the several factors involved are presented chiefly in graphical form; the dispersion relations alone are first considered, after which the chemical characteristics and the relations between chemical composition and optical constants are treated in summarized diagrams to indicate the methods which we adopted and which enabled us to solve the problems in a practical way in a short time. No consideration is given to the more fundamental problem of computing the optical constants of a glass of given chemical composition. The information at hand was not adequate for this purpose, and our war-time interest was not concerned with this problem, which still awaits satisfactory solution.

(26) Two gas collections from Mauna Loa. E. S. Shepherd. Bull. Hawaiian Volcano Observatory, 8, 65–67 (1920).

Through the courtesy of Dr. T. A. Jaggar, jr., of the Hawaiian Volcano Observatory, we received two tubes of gas which he collected in November 1919 from the flow on Mauna Loa. These are the first gases collected at this volcano. Dr. Jaggar had great difficulty in finding a suitable source for collecting, and greater difficulty in approaching it. The analysis of the gases accounts for part of the difficulty, since they show 2 and 8 per cent of SO_2 respectively. (The computation is made on the assumption that SO_2 acts as a perfect gas at 1200° C., which is not true; but this treatment allows comparison of this constituent with the others.) The combustible gases had practically all disappeared and the samples may be regarded as completely burned. It will be noted, however, that the amount of nitrogen present is not high and could not possibly account for the amounts of water present, namely, 67 and 75 per cent respectively. The argon group is present in rather larger amounts than at Kilauea, but amounts to a maximum of only 0.6 per cent. Free sulphur and chlorine were absent. Compared with similarly oxidized gases from Kilauea, the Loa gas seems entirely similar in composition, as was perhaps to be expected.

(27) Methods of increasing the precision of thermostats. W. P. White. J. Wash. Acad. Sci., 10, 429–432 (1920).

In mercury-contact thermostat regulators, the sensitiveness of the bulb depends on dimensions and materials and on a sort of lost motion in the contact itself, which nearly always varies between the limits 10μ and 40μ. The constancy attained depends on this and also on the temperature lag of the bulb. When high precision is sought, this temperature lag almost inevitably takes the form of phase retardation and damping of the temperature-wave which penetrates the bulb. On account of this phase retardation, it is usually impossible for a bulb, no matter how sensitive, to regulate to 0.001° in a uniform bath. If the surrounding temperature is also made very constant, the variable heating can be cut down and the temperature lag thus diminished; a precision even exceeding 0.001° can then be obtained. Two other ways of getting such precision are: to use a Gouy oscillating-wire regulator, and to put the regulator bulb close to the heater. This last method, however, while it gives rapid oscillations and therefore great steadiness, may show large variations with change in room-temperature or heating voltage.

(28) Optical glass and its future as an American industry. Arthur L. Day. J. Franklin Inst., 190, 453–472 (1920). (Papers on Optical Glass, No. 26.)

At the time of the entry of the United States into the World War in April 1917, optical glass was being made in this country by but one manufacturer. The quality of the glass was fair, but not comparable with the best European glasses. The maximum production was about 2,000 pounds per month. American requirements for war purposes, including both Army and Navy, were estimated by the General Munitions Board to be about 2,000 pounds per day.

The three glass-producing countries, England, France, and Germany, for reasons of national interest, chose to maintain the integrity of the national monopoly in optical glass existing in those countries before the war, and even under the pressure of war requirements the technique of optical-glass manufacture remained shrouded in the deepest secrecy.

In this emergency the Geophysical Laboratory, because of its experience with silicate solutions, was invited to try, if possible, to discover this technique and to aid in the manufacture of the glass required for fire-control instruments for all branches of the war service. This was done in collaboration first with the Bausch & Lomb Optical Company and later with the Spencer Lens Company of Buffalo and the Pittsburgh Plate Glass Company at Charleroi, Pennsylvania. The problem as confronted by the Laboratory consisted mainly in searching out American sources of supply for the purest raw materials for the glass and the containing vessels in which it was to be melted. In this it enjoyed the fullest cooperation from the United States Geological Survey and the Bureau of Mines, and many private sources of information. It remained then to ascertain the relation between glass composition and the optical qualities prescribed for particular instruments, and finally to learn the precise conditions necessary for melting these ingredients so as to secure complete homogeneity and a definite composition, and to cool and anneal the finished product to secure physical homogeneity or freedom from strain.

The work was successful even beyond the most sanguine expectations, and within a period of four months from our entry into the war the limited number of glasses needed by the War and Navy departments could be produced in a quality comparable with that which had hitherto been imported. From that time on the problem was chiefly in increasing the plant capacity in the various manufacturing organizations to meet the war requirements.

The total quantity of glass of optical quality produced under the direction of the Geophysical Laboratory amounted in all to something over 600,000 pounds, being about 97 per cent of the total quantity required and used by the United States Government for war purposes. The remaining 3 per cent was produced in part by the Bureau of Standards Laboratory at Pittsburgh, in part by Mr. Karl Keuffel in the Works Laboratory of the Keuffel & Esser Company at Hoboken. A few hundred pounds were permitted to be imported from France and England. No other glass was available to the Government for war operations.

(29) Memorial of George Ferdinand Becker. Arthur L. Day. Bull. Geol. Soc. Amer., 31, 14–25 (1920).

A review (with bibliography) of the life and scientific work of Dr. George F. Becker, for 38 years chief of the Division of Physical and Chemical Research of the United States Geological Survey, and initiator of the researches out of which grew the present organization of the Geophysical Laboratory.

(30) The crystal structure of some carbonates of the calcite group. Ralph W. G. Wyckoff. Am. J. Sci., 50, 317–360 (1920).

By the same general method that has been employed in studying cæsium dichloriodide and sodium nitrate, a unique solution has been obtained for the crystal structures of calcite and rhodochrosite. Of the assumptions commonly made in crystal-structure study, the only one required in this determination was that the atoms reflect X-rays in an amount roughly proportional to their atomic numbers. The structure of siderite was shown to be so nearly the same as that of rhodochrosite as to be indistinguishable by the means at hand. Magnesite was also found to give the same sort of pattern and hence to have the same general arrangement of atoms as the other members of the group.

The positions of the oxygen atoms, as determined by the present method and by the spectrometer results, are compared. In this particular case, the "normal" decline of intensities is in surprising agreement with the reflections. Evidence is obtained from these crystal structures to show the existence of groups of atoms, as carbonate groups, in the crystal. It is also pointed out that unless *every atom* in the crystal is electrostatically charged, the outside electrons of the atoms making up these crystals *can not* be arranged at the corners of cubes.

Some connections are pointed out between the development of faces on calcite and its crystal structure, and a way is indicated of deciding the most probable indices of a plane when they are in doubt. The bearing of these structures upon the question of what constitutes a series of isomorphous substances is mentioned.

A criterion is suggested for determining in the case of an hexagonal crystal, whether the fundamental unit in a rhombohedron or an hexagonal prism.

The use of gnomonic projection in studying Laue photographs is mentioned and a ruler is described, the use of which reduces the time and labor of making such projections. The effect of the voltage impressed on the X-ray tube upon the character of the Laue photograph is considered and the best conditions for operating a tungsten tube for this work are stated.

(31) The Katmai region, Alaska, and the great eruption of 1912. Clarence N. Fenner. J. Geol., 28, 28, 569–606 (1920).

A preliminary account has been presented in this paper of observations made by the writer as geologist of the expedition sent in 1919 by the National Geographic Society, in cooperation with the Geophysical Laboratory, to the Katmai region. As a result of this work, evidence has been found that affords a basis for extending considerably our ideas respecting the processes at work during the eruption.

It has been found that the volcanoes of this region, which form a continuation of the Aleutian loop or festoon, are situated in an area of sedimentary rocks remarkable for the absence of folding or obvious faulting. The more recent lavas are basic andesites, contrasting greatly in composition with the highly siliceous rhyolite of the last eruption.

In the area of the Valley of Ten Thousand Smokes it is believed that the injection of a sill or closely similar body of magma into the underlying strata at the beginning of the eruption caused shattering of the rocks above it, and these openings permitted the ascent of magma. The extrusion and inflation of this magma gave rise to a great ash-flow or sand-flow, analogous in many respects to the *nuées ardentes* of Pelée and La Soufrière, and led to the formation of the parasitic cone of Novarupta. The fumaroles are thought to be due to the continued evolution of volatile constituents from this body of

magma. The development of the new vent of Novarupta is ascribed to the enlargement of a channel along one of the fissures. The later extrusion of the stiff lava forming the dome of Novarupta is found to have been similar in many respects to that of the "spine" of Pelée.

At Falling Mountain the most interesting features are those resulting from fumarolic action. Evidence of a process of solution and transfer of rock material in the gaseous medium was found here, and the results of similar processes around the vents of the fumaroles in the valley were observable. It is suggested that the properties of the evolved gases indicated by this selective gaseous transfer may at times lead to results of great importance in volcanic processes.

A study has been made to determine the manner in which the top of Mount Katmai disappeared and the great crater-pit was formed. It seems quite certain that the material was not blown out directly, but must be accounted for otherwise. Crater subsidence may have been a factor, but it is believed that collapse of the crater-walls and incorporation of the material in the new magma were chief features. It is recognized that the latter process demands a large quantity of heat for its accomplishment, and the magma evidently was not at very high temperature prior to extrusion; therefore accessions of heat seem to be demanded. A considerable problem is thus presented, but it does not seem at all insuperable, and it is believed that the evidences of solution are so strong that they can not be disregarded.

One of the important features of the eruption brings up for consideration a phenomenon to whose significance little attention seems to have been paid hitherto. It is that of a gas-charged magma gradually developing the explosive condition after some interval has elapsed subsequent to its ascent from the depths. The Katmai magma seems to have followed this course, and the phenomenon is apparently not uncommon. This is believed to have great significance and to imply changes of physical environment during its ascent, effected with such rapidity that internal readjustments were not able to keep pace with them. Many of the current theories of volcanism are based upon a fundamentally different conception of the nature and properties of the magma. It is thought that it may be advantageous in many cases to consider matters from the new standpoint here suggested.

In other matters, also, theories that have been proposed and somewhat widely accepted are apparently not in accord with the evidence found here. It has not been possible in this article to discuss these matters exhaustively, and other matters of interest have not been touched upon. Fuller treatment willbe presented in articles to follow.

(32) American optical glass for American instruments. George W. Morey. Am. Photography, 14, 129-133 (1919).

A popular account of the development of the American optical-glass industry and of the manufacture of optical glass.

DEPARTMENT OF HISTORICAL RESEARCH.[1]

J. Franklin Jameson, Director.

The following report, the fifteenth annual report rendered by the present Director, covers the period of eleven months from November 1, 1919, to September 30, 1920. In most respects the Department had at the beginning of these eleven months extricated itself from the distractions attendant upon the war, and in general the year has been normal, except in so far as the heightened prices and labor-costs of the time have reduced the amount that such an establishment can accomplish per annum.

In the staff of the Department there has been but one change. Miss Esther Galbraith, after two years of most excellent service, resigned in August. Her place has not yet been filled, but during August and September Miss Elizabeth Donnan, formerly a member of the staff of the Department, but now an assistant professor in Wellesley College, kindly undertook for the time being the duties that had formerly fallen to Miss Galbraith.

From the beginning of February until the beginning of August, Professor John S. Bassett, of Smith College, cooperated with the Department as a Research Associate. His especial task was to begin, and to carry as far as the time would allow, the preparation of an edition of the papers, chiefly the letters, of Andrew Jackson. Extensive editions of the writings of Washington, John Adams, Jefferson, Madison, Monroe, and John Quincy Adams exist and are of well-known value to students of American history. The autobiography of Van Buren is in course of publication. Polk's diary, most of Tyler's letters, and (among contemporaries of Jackson who were not presidents) those of Gallatin, Webster, Clay, and Calhoun have been printed. The chief gap, it may fairly be said, in the published materials for the middle period of our political history, consists in the absence of any printed collection of the letters of President Jackson. This gap the Department has undertaken to fill, availing itself for that purpose of the aid of Professor Bassett. As the chief biographer of Jackson, he is already familiar with his manuscripts and no one is better qualified to edit them.

Much the largest part of the Jackson material still extant is in the custody of the Library of Congress. Inevitably, Professor Bassett turned first to that collection, and indeed his whole six months were spent there. By the kindness of the librarian, Dr. Herbert Putnam, and of Mr. Charles Moore, chief of the Manuscripts Division, he was given every facility for the prosecution of his work, and, laboring with great industry, succeeded within the six months in carrying out,

[1] Address: No. 1140 Woodward Building, Washington, D. C.

throughout the whole mass of Jackson manuscripts in the library, the processes of reading, comparing, selecting those letters which were to be copied for publication, and making such notes from others as would be needed for purposes of annotation. The work of transcribing for the press those letters which Professor Bassett selected has gone forward, in the hands of Miss Jane Boyd, through a large portion of the collection. It remains to collect those letters of Jackson which are to be found in other public depositories, such as the archives of the War Department, and those which are preserved in private hands. After selection and transcription, the work of annotation will be undertaken. The result will be a work in several volumes, undoubtedly of great value to the student of the whole Jacksonian period, from the early Tennessee period and the War of 1812 until the general's death.

During the greater part of his period of residence, Professor Bassett gave weekly informal lectures to the staff of the Department, most frequently basing his talk upon portions of the material which he was engaged in examining at the Library of Congress. His talks and companionship were of great advantage and pleasure to the Department.

As in previous years, acknowledgment is cordially made of the favors constantly shown to the Department, with the greatest liberality, by the officials of the Library of Congress, and especially by Dr. Herbert Putnam, the librarian, by Mr. A. P. C. Griffin, chief assistant librarian, by Mr. Charles Moore, chief of the Manuscripts Division, and by Mr. P. Lee Phillips, chief of the Map Division. Grateful recognition is also made of special courtesies extended by the authorities of the library of Harvard University, especially during the summer months, to several members of the staff, and of the courtesy shown by the New York Public Library in facilitating the work of Mrs. Surrey.

REPORTS, AIDS, AND GUIDES.

The "Guide to Materials for American history in Paris Archives," on which Mr. Leland has long been engaged, has been considerably advanced during the year, partly by labors on his part, but more largely by the work of his assistant, Mr. Abel Doysié, in Paris. Mr. Leland at the end of December resigned the position of secretary to the American Historical Association, which he had held for eleven years and which had brought heavy burdens upon him; and his occupancy of the position of secretary to the National Board for Historical Service, which during the war consumed nearly all his time, came to an end with the dissolution of that body in the same month; but he has found it impossible to release himself wholly or speedily from duties which befell him in connection with those two offices, but which could not be finished until well into the year 1920. Important secretarial duties in the work of organizing and setting in motion the American Council of Learned Societies, which owes its inception chiefly to his action as

secretary of the American Historical Association, inevitably continued during the early part of the year. In spite, however, of all these services, which in themselves were highly useful to the cause of historical learning in America, Mr. Leland has been able to do some work upon that volume of his Guide which it is intended to publish first, namely, that which catalogues the American manuscript materials preserved in the libraries of Paris, as distinguished from the Archives Nationales and the archives of various ministries and other governmental establishments in Paris.

Mr. Doysié, during the year, has finished his search of the library of the Ministry of the Marine, which contains not only a large collection of historical manuscripts, but also an important group of archives which has never been deposited in the Archives Nationales. It includes an important series of royal and ministerial acts relating to maritime, naval, and colonial affairs, to Canada, Louisiana, colonial defense, fisheries, commerce, the slave-trade, and pirates and privateers. Another depository, still in process of being explored, is the Dépôt des Cartes et Plans de la Marine. This contains maps, log-books, reports of explorers and navigators, and miscellaneous manuscripts, in such amount as to make it one of the most important depositories of American material, next to the colonial archives, in Paris. The Dépôt is divided into library and archives; the part called the library has been completed; the systematic examination of the archives is still going on. Mr. Doysié has also dealt in a similar manner with the Library of the Institute of France, the Library of the Senate, and the new acquisitions of the Bibliothèque Nationale.

Mrs. Surrey has continued her work of editing for publication a calendar of papers in Paris archives and libraries bearing on the history of the Mississippi Valley, based on notes taken in Paris under Mr. Leland's direction. Working with great assiduity, she has now completed a total of 22,000 cards. Her work, somewhat interrupted at one time by illness, has been carried on in the New York Public Library.

The preceding annual report described (pp. 176–177) the work carried out in the archives of the Netherlands by Mr. A. J. F. van Laer, consisting in the gathering of notes for a full report on the materials for American history in the archives of that kingdom. It is necessary to report, with much regret, that the duties of Mr. van Laer in Albany, as archivist of the State of New York, combined at times with imperfect health, have prevented him from making much progress in the redaction of his report in form for printing. It is hoped, however, that he may soon be able to make more rapid progress.

In connection with the general planning for and examination of archival materials in the British West Indies, set forth in pp. 177–179 of the preceding report, an expedition was made to Bermuda at the

end of March by Professor Herbert C. Bell, of Bowdoin College, and Miss Pierce, of the regular staff of the Department. A domestic calamity calling him home greatly abridged the time which Mr. Bell was able to spend in the islands, but, by the joint efforts of the two agents, notes were taken from which an adequate account of the archives of Bermuda can be compiled, on a scale comparable to that with which the archives of the other West Indian islands will ultimately be treated. Bermuda was never a large or important colony, but its colonial history begins so early, and its archives have been so much less affected than those of the Antilles by wars, conquests, the ravages of insects, earthquakes, hurricanes, and other incidents of tropical climate, that they form a long and large series, having a considerable significance for the student of British colonial history in general and even of the mainland colonies in particular. Mr. Bell and Miss Pierce were with great courtesy permitted to examine nearly all the papers down to the year 1854, but not beyond that point. The thanks of the Institution are especially due to Mr. E. A. Gosling, assistant secretary of the colony, who gave much useful help to their researches.

In the work upon the "Atlas of the historical geography of the United States," Dr. Paullin, with the aid of the draftsman, Mr. J. B. Bronson, has completed several series of maps belonging to the general division relative to lands and land-policy. These series are those relating to colonial grants, colonial claims and possessions, the land claims of States and their cessions of land to the United States, the cessions of land by Indian tribes, the States projected and formed west of the Alleghenies, the military reserves, and the territorial acquisitions of the United States. He has also prepared the letterpress accompanying all these series, excepting the last. He has prepared the text accompanying those maps respecting immigration and foreign population which were reported a year ago as completed, and has made progress on the maps intended to illustrate the development of federal surveying and the grants of land to the States for the support of education.

Mr. David M. Matteson, of Cambridge, Massachusetts, though diverted during about half of the months of the year to work for others, has during the other half made substantial progress in his work for the Institution, the work of searching in printed catalogues of manuscripts in European libraries for those items which disclose and describe manuscripts relating to American history. Having practically completed the bibliographical search for titles of books and articles in which such catalogues or minor lists are included, he has proceeded to the search for American items in those catalogues and lists. Thus far he has carried this process through the letter M, in alphabetical order of towns. The total number of manuscripts bearing on American history thus revealed is not numerous, but hardly one of them was known before to those students who would be most interested in their existence. It

should be noted that the American manuscripts in the libraries of London, Oxford, Cambridge, and Rome, four of the five European cities containing the greatest number of such manuscripts, have already been listed in publications of the Department, namely, in Andrews and Davenport's "Guide" for the libraries of London, Oxford, and Cambridge, and in Mr. Fish's volume on Roman and other Italian archives, while Mr. Leland's first volume will cover the numerous volumes in the libraries of Paris.

TEXTUAL PUBLICATIONS OF DOCUMENTS.

Miss Davenport has been able to make ready for publication eight more treaties, 1667–1670, for the second volume of her "European Treaties bearing on the History of the United States."

Dr. Burnett has advanced the final preparation of the manuscript of his "Letters of Members of the Continental Congress" to the end of the year 1782, nearly completing the fourth volume. The systematic alteration of the cross-references in footnotes, alluded to in the last annual report, has been carried through volume II. Meantime, the first volume, running from the beginning of Congress in 1774 to July 4, 1776, has been set up by the printer and read in galley-proof. The work will consist of six volumes.

In the series of volumes which are being prepared by Dr. Stock, the "Proceedings and Debates of Parliament respecting North America," the work at present going on is that of annotating the texts, gathered together long since. This work of annotation Dr. Stock has now carried to the end of the year 1645. Meanwhile, however, a large number of petitions to Parliament, 1628–1645, has been obtained from the manuscripts of the House of Lords, and the bringing of these into the series has entailed much additional labor. Dr. Stock has also been compelled to spend no small part of his time in clearing off certain pieces of work for the National Board for Historical Service which fell to him as its assistant secretary and which survived the dissolution of that body.

Miss Donnan, in spite of her college duties and of those which, as mentioned in a previous paragraph, she kindly undertook in substitution for Miss Galbraith, has found time to advance a little her collection of documents and narratives illustrating the history of the African slave trade and the importation of slaves into English America. The chief piece of such work has been the examination of the files of the *Georgia Gazette* of the colonial period. Little further progress can, however, be made toward the completion of this volume until Miss Donnan is able (it is hoped during the summer of 1921) to investigate the materials for her subject in the British Museum and the Public Record Office.

Prolonged illness prevented Mrs. Catterall from doing any work upon her collection of material for the history of slavery derived from the American judicial reports. As the period reported upon closes, however, she is ready to resume her work.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the *American Historical Review* has been carried on in the office of the Department and by its staff. The American Historical Association and various other historical organizations have been given such aid as could appropriately be rendered in respect to investigations in Washington and other services, and many queries from individuals have been answered. The archives of Washington are still a trackless wilderness. Students remote from Washington can not hope to derive much benefit from them except through the mediation of the staff of this Department, which has by this time acquired a considerable familiarity with the dispersed, ill-kept, and chaotic deposits which, to our great discredit, are still our substitute for a proper national archive.

The Department has also gladly made itself useful to historical inquirers in procuring transcripts from foreign archives, especially, this last year, in the case of Seville and Paris.

In the matter of the transcripts made in Seville for the Carnegie Institution by the late Dr. Adolph F. Bandelier, not much progress has been made by Dr. Hackett during these eleven months. All the work of copying for the printer and nearly all of the translating having been finished, progress now depends not upon the labor of assistants but upon that of Dr. Hackett himself. It so happens, however, that the resignation of another teacher in the University of Texas practically compelled Dr. Hackett to accept a permanent engagement there as adjunct professor, with new work to organize and, even in the summer, exigencies of the university made it seem important for him to spend a part of the time in Mexico. Therefore, his work of editing the documents and writing the introductions for the several groups into which they have been divided has been greatly held back and is still far from complete.

DEPARTMENT OF MARINE BIOLOGY.[1]

ALFRED G. MAYOR, DIRECTOR.

The major objective of the year has been an expedition to complete the intensive study of the reefs of American Samoa which we commenced in 1917. In this connection it is a privilege to express our gratitude for many acts of kindness and interest on the part of Commander Warren Jay Terhune, U. S. Navy, governor of Samoa, who gave the Director the opportunity of visiting Rose Atoll, which no man of science had seen since 1839. We are also indebted to Mr. Herbert H. White, president of the South Seas Pacific Company, who kindly permitted the members of our expedition to occupy the commodious warehouse of this company at Pago Pago and use it as a laboratory.

It is also a pleasure to speak of the kindness of Professor T. C. Frye in granting the facilities of the Friday Harbor Laboratory on Puget Sound for the use of Professor A. L. Treadwell, while he was engaged in the study of annelids on the Pacific Coast. Also, Rev. C. J. Kinnersley, of Leone, Tutuila, who was so kind to Professor Daly in 1919, again rendered effectual aid to our expeditions in 1920 by entertaining Professors Treadwell and Setchell.

Due to the generous interest of Coleman Wall esq., curator of the Fiji Museum, we were presented with excellent fossils from the elevated reef at Walu Bay, Suva Harbor, now about 60 feet above tide-level.

Official sanction was kindly granted to the expedition by a letter of recommendation from Hon. Franklin D. Roosevelt, Assistant Secretary of the Navy, to his excellency the governor of Samoa.

On September 9–10, 1919, the center of the most violent hurricane yet recorded by the Key West Weather Office swept over Tortugas, Florida. The wind was especially severe between 12 p. m., September 9, and 2 a. m. September 10, the anemometer breaking at 92 miles per hour, but the maximum velocity was estimated at about 120 miles.

The barometric gradient was about 1.5 inches in 30 miles, this being the steepest yet observed in the Florida region. Thus, according to H. B. Boyer, meteorologist of the U. S. Weather Bureau, the lowest barometer at Key West was 28.83, while at Rebecca Shoal Lighthouse it was 27.68 and at Tortugas 27.57. The two dock-houses, dock, wind-mill, and old laboratory building at Tortugas were so seriously damaged as to necessitate reconstruction, but the main laboratory, building-shop, and pumping-station escaped without serious injury. Temporary repairs to secure the property from further deterioration were made at once, but owing to the unprecedently high cost of materials and labor, it was deemed inadvisable to open the laboratory in the spring of 1920, but instead we completed the in-

[1] Situated at Tortugas, Florida.

tensive study of the coral reefs of American Samoa which was commenced in 1917.

The following investigators studied under the auspices of the Department of Marine Biology during the year:

L. R. Cary, Princeton University, Samoa, July 5 to 28. Alcyonaria, and study of material from borings through reefs.

R. T. Chamberlin, Chicago University, Samoa, July 5 to 28. Geologic relation of Tutuila Island to its surrounding reefs.

U. Dahlgren, Princeton University. Electric organs in fishes.

E. N. Harvey, Princeton University. Chemistry of animal luminescence.

C. B. Lipman, California University. Samoa, May 31 to June 22. Bacteria of the Pacific in relation to precipitation of calcium carbonate.

W. H. Longley, Goucher College. Samoa, July 5 to August 27. Colors and patterns of reef-fishes in their relation to natural selection.

A. G. Mayor, Carnegie Institution of Washington. Samoa, Tonga, and Fiji, March 28 to July 28. Biology and growth-rate of coral reefs.

F. A. Potts, Trinity Hall, Cambridge University, England. Samoa, Tonga, and Fiji, March 28 to July 28. Growth-rate of invertebrates in tropical Pacific.

W. A. Setchell, California University. Samoa, May 31 to July 28. Marine and land plants of Samoa.

A. L. Treadwell, Vassar College. Puget Sound, Fiji, and Samoa, February 13 to June 22. Marine annelids.

Mr. John W. Mills, chief engineer of the laboratory, accompanied us to Samoa and Fiji and devised an ingenious improvement in the core barrel by means of which a core may be brought up, even when the material being bored through is loose sand. Using this apparatus, he made two borings, one of 120 feet through the Utelei reef on the west side of Pago Pago Harbor, 925 feet from shore, and another of 156 feet through the Aua reef on the east side of Pago Pago Harbor, 512 feet from shore. Hard basalt was found at the bottom of the reef in each case, showing that the modern fringing reefs in Pago Pago Harbor have grown outward over basalt and not over ancient submerged reefs. On the Utelei side of the harbor our borings show that the reef has pushed outward from the shore over a basaltic slope or submarine platform, the maximum depth of which is 120 feet; but on the Aua side of the harbor the boring was made in the submerged trough of a valley, the hard basaltic bottom of which, 512 feet from shore, was found at a depth of 156 feet below present sea-level. Thus the modern reefs of Tutuila appear not to be superimposed upon the ancient reefs now submerged to a depth of about 180 feet, but to be independent structures which have grown out over the submerged basaltic slopes of the island after the sea had assumed its present level.

The nearly completed U. S. hydrographic chart of Tutuila shows that the island was once largely surrounded by a barrier reef which, in some places, especially along the north shore, had fused with a fringing reef that had grown outward from the shores. The top of these reefs is now dead and submerged about 180 feet. In later times the sea stood about 10 feet higher than at present, while the prominent

sea-cliffs now seen around the islands of American Samoa were cut. Finally the sea sank to its present level, and then a new set of reefs began to grow outward from the shores to form the present fringing reef of Tutuila. Where the submarine slopes are gradual, as at the inner ends of the drowned valleys, the reef is wide, but they are narrow where the slope is steep, as at the ends of the promontories.

Professor Rollin T. Chamberlin, who made a special study of the relation between the reefs and the volcanic shores of the island, and who presents a report published herewith, finds that the ancient barrier and fringing reefs which once surrounded the island and are now drowned grew upon a platform which had been cut by the sea and afterwards submerged and not upon the unaltered slopes of the island. Thus the Darwin-Dana theory does not apply to Tutuila. Also, the bottom of the platform upon which these old reefs grew is now submerged at least 400 feet below present sea-level, while the glacial-control theory postulates a submergence of not more than half that shown by the ancient platform of Tutuila. The failure to find coral upon the 8-foot elevated shore-bench around Tutuila is remarkable, in view of the fact that it is found in the emerged limestone rim of Rose Atoll, Samoa, remnants of which still project about 8 feet above present sea-level. This isolated atoll is about 140 miles to the eastward of Tutuila, and when the sea stood at its highest level lithothamnion and coral grew in the shallow water of the atoll rim, thus indicating that the climate of Samoa was at that time tropical.

While we were in Fiji, Coleman Wall esq., curator of the Fiji Museum, kindly gave us a small but excellent collection of fossil lamellibranchs and sharks' teeth from the quarry in the elevated limestone at Walu Bay, Suva Harbor, Fiji. These will be studied by Dr. T. Wayland Vaughan. A few other specimens were collected by the Director in Fiji and at Vavao, Tonga, and it is hoped that their study may in the end contribute toward a determination of the age of the ancient elevated coral reefs of the central Pacific Islands. The matter is, however, complicated by the condition that some forms may have died out in the West Indian region and tropical Atlantic and have still survived in the tropical Pacific until more recent times. The problem of the age relation of the reefs of the Pacific to those of the Atlantic can be solved only by an intensive study of the conditions in well-selected localities showing elevated reefs, as well as by borings through submerged reefs. The fact that the ancient reefs have become partly dolomitized, while those of modern times appear not yet to have undergone this change, may serve to distinguish between them in making borings. Especially, a comparative study must be made of the elevated ancient reefs of Fiji, Tonga, and the New Hebrides.

It may be significient that living atoll rims and barrier reefs throughout the tropical Pacific are of remarkably uniform width and not so

wide as many of the ancient extinct barrier reefs. Thus they appear to be of relatively recent formation and all of about the same age, and this fact lends support to Daly's idea that the living reefs of the Pacific have grown upward upon submerged platforms since the end of the last glacial period.

In one respect, however, Tutuila seems to lend little support to Daly's glacial-control theory, for when the sea stood about 180 feet lower than at present there were wide fringing reefs and barrier reefs around the island, and thus the climate was apparently tropical while according to the theory the glacial period was then at its height.

Moreover, Daly and Chamberlin were unable to demonstrate that when the sea stood highest, coral reefs grew around the island, and thus if present were probably not extensive.

In Samoa corals were planted in concrete and grown at various depths from 50 feet to near the surface. The maximum growth-rate appears to be in places washed by pure agitated ocean water of moderate depth, as on the seaward slopes of the reefs. Here about three quarters of the surface is densely covered by large, thick-stemmed heads of *Acropora* and *Pocillopora*, these being the coral genera which grow most rapidly. Our observations in Samoa show that a reef composed of the slow-growing massive *Porites*, such as live in impure water and in silted regions, might grow upward 120 feet in 2,000 years, but *Acropora* grows at about four times this rate. Thus the modern fringing reefs of Samoa could readily have been formed since the close of the last glacial period, and may not be more than 30,000 years old.

The fast-growing *Acropora leptocyathus* and *Acropora arcuata* cluster thickly along the breaker-washed overhanging edge of the reef, and when they die they are largely preserved in place by being covered with lithothamnion. This lithothamnion veneers all the dead corals and smoothes the surface, forming a ridge about 6 to 8 inches above low-tide level up which the breakers glide, constantly losing force, so that they can not destroy the dense clusters of delicately branched *Acropora* which grow in the shallow water of the reef-flat just back of the crest of the lithothamnion ridge.

Below the overhanging seaward edge of the reef there is a sheer precipice usually from 2 to 9 fathoms in depth. At the foot and over the steep sides of this precipice one finds a dense growth of *Acropora* and *Pocillopora*, and these corals constitute the rugged floor at the base of the precipice. The surges drive to and fro over this uneven floor, breaking off slender tips of corals, so that only tough-stemmed forms can survive in this agitated region, which is constantly worked over by the strong currents driven by the breakers. Broken corals are jammed tightly into crevices, and dead ones are covered by layer after layer of lithothamnion, and thus a compact wall is built upward, while the overhanging lithothamnion-protected, breaker-washed seaward edge of the reef advances over it and covers it with its talus.

At depths greater than 7 fathoms the coral heads become small and appear to grow slowly; and in this region the dead, loose talus of the reef accumulates in jagged masses, the whole sloping downward at an average inclination of about 30°, which appears to be the angle of repose of the material.

The lithothamnion which veneers the seaward edge of the reef does not thrive except in agitated water, and it dies in the quiet region back of the surges, and here the ridge breaks off in fragments to form the loose, erratic blocks of dead coral veneered with lithothamnion which the storm waves scatter over the floor of the reef-flat shoreward of the lithothamnion ridge. Everything is loose in this region, whether it be a coral head hundreds of pounds in weight or a mere grain of corroded lithothamnion. Our studies show that these broken masses of dead coral scattered over the reef-flat disappear at such a rate that on the mid-region of the Aua reef, rocks of this sort weighing 5.1 pounds lose one-fifteenth of their weight in a year. The loss due to this attrition and removal of sand by currents is offset by the growth of coral over the reef-flat, and thus as a whole it maintains itself close to the level of low-tide, and is not disintegrated to form a lagoon back of the growing seaward edge of the reef. Indeed, in the Pacific, fringing reefs appear to be maintaining themselves as such and are not changing into barrier reefs by shoreward solution of their limestone, nor is there any evidence to support Darwin's view that atoll rims were once barrier reefs. Apparently the living reefs of the Pacific have arisen upon previously submerged platforms or ancient submerged reefs, and these platforms have had a complex history which is at present imperfectly understood.

The history of Tutuila, according to Dr. Rollin T. Chamberlin, appears to be as follows: A platform about 2 miles in width was cut by marine erosion around the island. Then this platform became submerged, while at the same time the island tilted so that the platform sank to a slightly greater depth on the southeast than along the north shore. Then reefs grew around the island, and on the north shore, where the platform was shallow, the fringing reefs largely fused with the off-shore barrier reef; but on the south shore, where the platform was submerged more deeply, the fringing reef in most places did not fuse with the barrier reef, but the lagoon remained intact between them. Later a submergence of about 190 feet occurred and the sea cliffed the shores, and finally the sea-level sank about 10 feet and then the modern fringing reefs began to grow outward from the shores over the seaward slopes of the island.

Captain Frank A. Potts, of Trinity Hall, Cambridge University, England, made a special study of the growth-rate of invertebrates other than corals and finds, according to his report, that *Lepas* and *Teredo* in Pago Pago Harbor, at 26° to 30° C. grow much more rapidly than they do in temperate regions, but in other forms, such as hydroids

and colonial tunicates, the growth-rate is comparable with that in the colder waters. In this connection we might mention the fact that the growth-rate of coral in Samoa is nearly twice as rapid as that of corresponding genera, as determined by Vaughan, in the Florida-Bahama region.

Professor C. B. Lipman commenced a study of the bacteria of the sea-water of Samoa in an attempt to explain the fact that in the tropical Atlantic we find wide areas of precipitated calcium carbonate, while these are deficient in the Pacific. The precipitation of $CaCO_3$ in the Florida-Bahama region has been attributed to the denitrifying influence of the bacillus *Pseudomonas calcis* discovered by G. Harold Drew; but, as a result of later studies by McClendon at Tortugas, there seems reason to suspect that other causes may contribute to this precipitation to an even greater degree than does Drew's bacillus.

There is much pelagic plant-life, such as *Sargassum*, *Trichodesmium*, etc., in the tropical Atlantic, but this is deficient in the warmer parts of the tropical Pacific, and the deficiency of precipitation of calcium carbonate in the Pacific may be correlated with the deficiency of floating plants. Professor Lipman isolated a number of bacteria in the Samoan waters, among them Drew's *P. calcis*, which, when grown in natural sea-water, precipitates a slight amount of calcium carbonate but does not denitrify the sea-water in the process. It will be necessary for Professor Lipman to perform corresponding experiments in the tropical Atlantic before final conclusions can be drawn.

Professor William A. Setchell made a collection of the marine algæ and incrusting plants of the reefs of Samoa, in order to determine their relation to reef formation. In addition, he collected the terrestrial plants of Tutuila and obtained their native names, an account of the uses made of them by the Samoans, and the tradition of their place of origin.

Professor A. L. Treadwell, having completed a notable study of the Eunicidæ of the Florida-Bermuda West Indian region, accompanied us to Samoa and Fiji in order to extend these studies to the forms found in the Pacific reefs. While en route to the tropical Pacific he was enabled, through the kindness of Professor T. C. Frye, to spend several weeks at the Friday Harbor Marine Laboratory of the University of Washington in Puget Sound, thus broadening the scope of his studies.

Professor William H. Longley remained two months in Samoa, making a study of the fishes of the reefs, in order to determine the underlying laws in obedience to which their colors and patterns may have been evolved. He is thus continuing in the Pacific the elaborate studies he has for some years pursued at Tortugas and in the West Indies. By using a diving-hood and observing fishes in their natural surroundings he has gathered a great mass of valuable data, and concludes that natural selection is the chief underlying factor which has determined the coloration of these fishes.

Alfred G. Mayor completed the measuring, weighing, and photographing of all corals which had been under observation at Samoa and Fiji, some of them having been observed since 1917. The corals on the barrier reef off Suva Harbor, Fiji, had made little or no growth, and large areas of the reef had died since August 1918. A clue to the cause of this abnormal death-rate of corals in Fiji may be found in the history of the Samoan reefs in 1920. Thus, from May 15 to 21, there were exceptionally low tides, accompanied by unusual calm and heavy rains, and thousands of heads of *Acropora leptocyathus*, which were exposed to the rain and were above the wash of the waves, were killed. Even more destructive was the 37.5 inches of rain which fell at Pago Pago between June 28 and July 1, 1920. The whole inner half of the barrier became covered with densely muddy water, so that one could not see an inch beneath the surface. We found that each cubic yard of this surface-water contained 1 ounce avoirdupois of fine brown mud. This killed thousands of *Acropora arcuata*, but the *A. leptocyathus* were not so readily affected. In places near shore many large heads of *Porites*, which were more than 50 years old, were killed, and possibly some such condition may have largely killed the reefs off Suva, Fiji, during 1918–1920.

It was found that reef corals are not very sensitive to even large quantities of CO_2 in the sea-water, for we introduced carbon-dioxide gas into the water until the PH declined from 8.25 to 5.9 PH, thus becoming decidedly acid at 28° C. The introduction of the carbon dioxide displaced some of the oxygen from the sea-water, but it was found by means of Winkler's method that the rate of oxygen consumption by the corals was simply proportional to the concentration of oxygen in the sea-water and no toxic effect due to CO_2 could be determined after 2 hours' immersion in the acid sea-water. The concentration of oxygen in sea-water over shallow reef-flats varies greatly. Thus, on the Aua reef, in water about 5 inches deep, impounded for 2 hours by the low tide, the oxygen rose from 4.07 c. c. per liter to 8.44 c. c. per liter, the temperature rising from 26.7° to 27.4° C., and the salinity changing from 34.7 to 34.79. The corals were uninjured by this change, and the effect was doubtless due to photosynthesis by plants growing over the reef.

Professor L. R. Cary continued his observations on the growth-rate of *Alcyonaria* in Samoa, and he will make a special study of the biological constitutents of the borings through the Utelei and Aua reefs in order to determine the share taken by madreporarian and alcyonarian corals and by limestone-forming plants in building up the reefs.

Professor Rollin T. Chamberlin made a study of the geologic history of the living and extinct reefs surrounding Tutuila, and we have already quoted from his preliminary report, which he publishes herewith.

Professor E. Newton Harvey continued his experiments upon the chemical nature of the substances which produce luminescence in

animals, and he visited the island of Banda where he obtained material from the large luminous organ of a fish which is used as bait in this region.

Professor Ulric Dahlgren also continued his studies of the electric organs of fishes, using specimens of *Gymnotus* which had been collected in British Guiana by Dr. William Beebe.

Accompanied by Captain Potts, the Director attended the International Scientific Congress of the Pan Pacific Union at Honolulu. This meeting afforded an exceptional opportunity for discussing problems of the coral reefs of the Pacific with experts such as Andrews, Hedley, and Vaughan, from Australia and America.

We found that the reefs of Oahu Island lack the lithothamnion ridge which is so well developed along the seaward edges of most Pacific reefs. Due to the absence of a lithothamnion ridge, the reefs are not well protected from the sea and resemble those of the Atlantic in that their sea fronts do not overhang and they lack the well-defined seaward precipices seen elsewhere in the Pacific. Indeed, these subtropical reefs of Oahu are practically composed of only two genera of corals, *Porites* and *Pocillopora*, *Acropora* being absent. Actininians, starfishes, mollusca, and halimeda are rare, but certain seaweeds (such as *Ulva*) are more abundant than on the reefs of warmer parts of the Pacific.

The high cost of reconstruction prevented our opening the Tortugas laboratory during 1920, but on the other hand, we took advantage of the opportunity to complete the only intensive study yet undertaken of a volcanic Pacific island and its reefs. While in itself the study of so restricted a region may have little general significance, yet when well-selected islands, as in the Society Group, Fiji, the barrier reef of Australia, and the Philippines, have also been intensively studied and compared, light may be thrown not only on the general theory of reefs, but upon the genesis of the submerged platforms of the Pacific and the relative age of the fossil-bearing limestones as compared with those of Europe and America. The Department of Marine Biology is much more than a mere laboratory, for it is essentially an agency for the study of biological problems of all oceans. Starting with Tortugas as a base, the logic of our studies has often led us far afield. Thus, the work begun by Vaughan, Drew, and others upon the coral reefs of Florida has been extended to the Pacific; Treadwell's work upon the Eunicidæ and Clark's upon the echinoderms of the Florida-West Indian region made it desirable that their observations be extended into the tropical Pacific. Longley's submarine studies of the coloration of the reef fishes of Florida in relation to evolution and natural selection would have lacked general significance had they not been carried on also in the tropical Pacific. From the standpoint of zoology, paleontology, and geology, accurate comparisons between conditions in both

oceans are essential, and the Department of Marine Biology is one of the few existing agencies which is free to conduct such studies.

The following publications, representing work done wholly or in part under the auspices of the Department of Marine Biology, have appeared during the year:

CUSHMAN, J. A. 1920. Observation on living specimens of *Iridia diaphana*, a species of Foraminifera. Proc. U. S. Nat. Mus., vol. 57, 153–158, pl. 19–21.

HARVEY, E. N. 1920. The nature of animal light. IX+182 pp., 33 figs.

MAYOR, A. G. 1920. The effect of diminished oxygen upon the rate of nerve-conduction in *Cassiopea*. Amer. Jour. Physiol., vol. 51, 543–549.

———. 1920. The reefs of Tutuila, Samoa, in their relation to coral-reef theories. Proc. Amer. Phil. Soc., vol. 43, No. 3, 14 pp., 3 figs.

BARTSCH, PAUL. Experiments in the breeding of Cerions. Paper from the Department of Marine Biology, vol. XIV, Carnegie Inst. Wash. Pub. No. 282, 56 pp., 59 pl.

MORTENSEN, TH. Studies in the development of Crinoids. Paper from the Department of Marine Biology, vol. XVI, Carnegie Inst. Wash. Pub. No. 294, IV+94 pp., 28 pls., 10 figs.

REPORTS OF INVESTIGATIONS.

Studies of Alcyonaria and of Borings through Reefs of Samoa, by Lewis R. Cary.

The remeasuring of the recorded alcyonarian colonies growing on the reefs at Utelei, Pago Pago Harbor, Tutuila, Samoa, after a period of approximately two years from the time of the last measurements, shows that nearly all of the colonies could be recognized, and that in most instances the increase in size had been proportionately as great as during the first year for which the records were kept. Especially striking was the manner in which the stony corals had been overgrown by the *Alcyonaria*, so that in many instances the several alcyonarian colonies had come in contact, completely covering the less rapidly growing forms, the living tissues of which had entirely disintegrated.

A third boring on the Utelei line, 925 feet from the shore, which was made during the past summer, reached the underlying basalt after having passed through 124 feet of coral. This boring completes the evidence that this reef at least rests upon a substratum which for as much as 350 feet inward from its outer margin has been eroded to a practically level surface at a depth of approximately 20 fathoms below present low-water level. The inner boring, 280 feet from shore, where the substratum was reached at a depth of 68 feet, indicates that the planation to the lower level had not at this point extended inward to the present shore-line by somewhat more than the above-mentioned distance. Since, however, the cove at Utelei is situated well within the harbor, with a prominent headland protecting it from the direct effect of the strongest wave-action, it appears not unreasonable to suppose that in more exposed locations, for example at the harbor entrance or on the outer shore of the island, the erosion would have extended nearer to the present shore-line than at Utelei.

The character of the material brought up in the core-barrel, or in the "calyx-barrel" above the former, showed that the constitution of the reef at the 925-foot boring, which was about 20 feet from the reef-margin, differed in no essential respect from that indicated in the earlier, more shoreward borings. Sand was found abundantly in the upper 50 feet of the reef, with occasional solid lumps of massive stony coral or alcyonarian spicules; but the framework of the reef was, as usual, made up of branching coral, in the interstices of which the sand occurred in larger or smaller pockets. Throughout the lower por-

tion of the boring the coral had undergone the changes already observed in material from the previous borings, which had led to a decided change in the color and, to some extent, in the chemical constitution, the original white coral having been replaced to a great extent by extraneous material. Whether or not this change has taken place after a partial solution of the original skeletal mass is not apparent from a superficial examination of the core and can be determined only after an examination of sections, and possibly after chemical analysis.

The Geological Interpretation of the Coral Reefs of Tutuila, Samoa, by Rollin T. Chamberlin.

The origin of coral reefs having long been a topic of much debate, one of the objects of this expedition to Samoa was an intensive study of the reefs of the island of Tutuila, for the light which they might throw upon this controverted question. For the correct interpretation of these reefs a knowledge of the physical history of the island was deemed essential. In an endeavor to unravel the sequence of events and the stages in the growth and development of the island, three weeks were spent on Tutuila, in July 1920, investigating the shore-lines, the erosion profiles, and other physiographic and geologic features which are the present keys to the geologic past.

The island of Tutuila is a volcanic pile whose slopes have been attacked by the sea until a broad wave-cut platform, 2 miles in width, has come to surround the island. This broad shelf of planation, originally cut in the volcanic rocks not far below sea-level, now lies at least (though probably not much more than) 400 feet below sea-level. Streams on land cut deep valleys adjusted to the shores about 400 feet below the present strand-line. On the outer margin of the wave-cut platform, corals commenced to build a barrier reef, while a fringing reef grew outward along the shore. The island seems to have sunk somewhat relative to the sea, accompanied by tilting which submerged the south side more deeply than the north side. In the shallower water on the north side of the island the fringing reef, owing to the rapid growth of coral there, has in places become merged with the barrier reef. On the south side, where the water was deeper, the reefs are narrower. Subsequently the island became progressively submerged, though there may have been several halts and oscillations in this general movement. The last important strand-line before the present level was attained stood somewhat more than 10 feet above the present high tide, as evidenced by the conspicuous wave-cut benches seen on nearly all the headlands of the island.

Tutuila, therefore, is consistent with the Darwin-Dana coral-reef hypothesis to the extent that a submergence of 400 feet has occurred since the corals began to form the old barrier reef; but in other respects it does not fit the requirements of that hypothesis, inasmuch as the barrier reef, instead of being built up several thousand feet from the slopes of a sinking island, is found to be rooted on a broad, wave-cut platform which, slightly submerged, afforded favorable conditions for coral growth.

With respect to the glacial-control hypothesis, the shelf 400 feet below present sea-level is more deeply submerged than that hypothesis would require. If the broad platform were in reality cut during the comparatively brief stages of maximum glaciation and consequent low level of the oceans, according to the glacial-control hypothesis, a subsequent additional relative rise of the sea of some 200 feet would still be necessary. This is possible, but the assumption must necessarily take away much of the force of the glacial argument as applied to Tutuila. The lowered level of the oceans during the glacial epochs of the Pleistocene must inevitably have had its effects on the shores, but the

Tutuila studies favor the belief that the broad platform fringing the island, which has made it possible for the barrier reef to form, need not, in the main, have been cut under the conditions of glacial control.

The Fishes of Samoa, by W. H. Longley.

Samoa so abounds in fishes that 7 weeks spent in the islands proved too short a time to become thoroughly acquainted even with those species which occur in Pago Pago Harbor. The following paragraphs, therefore, embody only the results of a preliminary investigation of the fishes of the group.

Between the 5th of July and the 24th of August, 150 species were identified and 47 additional were distinguished without positive identification. Some of those identified, such as *Pseudupeneus porphyreus* and *Balistes bursa*, have not been reported from the islands hitherto. Among the species recognized but not to be identified by aids available at present a number will prove to be new to Samoa, if not new to science.

Not at every point, however, did investigation extend the list of Samoan fishes. In two cases it appears that systematists have recognized as distinct species what are only alternative color-phases of a single one. This is true of *Variola louti* and *V. flavimarginata*, as well as *Pomacentrus nigricans* and *P. albofasciatus*. In the case of either pair of forms the actual change from the one to the other may be observed in the field, though (by reason of its abundance) more readily in the case of *Pomacentrus* than *Variola*.

Of 197 species that came under observation, 56 are able to change color, shade, or pattern. Some, indeed, are changeable in all three respects. It is to be anticipated that an increase both in the absolute and relative amount of variability observed will follow more extended study.

To determine under what conditions the varied color-phases of the changeable fishes are displayed, and what relation both changeable and unchangeable hues bear to those of the normal surroundings of the various species, is the chief purpose of the investigation. To settle these points it is imperative to secure detailed information regarding the distribution and behavior of each species. This information must be gathered piecemeal, as opportunity offers. Until the investigation is far advanced it is therefore of a heterogeneous character and not readily summarized; but in general it may be said that the more narrowly a fish is confined to a certain environment, or the more commonly it occurs in such, the more clearly its color tends to reproduce those dominant in its surroundings.

This applies to single species, such as *Abudefduf dicki*, which is found in the neighborhood of *Acropora*, more particularly perhaps about *A. leptocyathus*, whose brown color it repeats. It also applies very clearly to such groups as *Pseudupeneus multifasciatus*, *Halichœres trimaculatus*, *Scolopsis trilineata*, *Balistapus aculeatus*, and *Monotaxis grandoculis*, which may be seen together over clear sand, to the shade of which they are without exception capable of adapting themselves. It also applies most strikingly to a number of species which to a greater or less degree are capable of putting off their bottom-colors when they rise toward the surface in deep water. No fish may more justly exemplify this class than the great surgeon-fish *Hepatus matoides*, which, when near bottom, may be black except for its tail and particolored yellow pectoral fin, but which 25 feet higher in the water, away from the reef-face, appears in pure pale blue-gray of lowest visibility.

In conclusion, the work of the past season shows that Samoa possesses a very large and diversified fish fauna, and that Pago Pago Harbor is so large, possesses such a degree of protection from the ocean, and has a shore-line of

such varied character that, between June and September at least, its fishes may be studied most advantageously, in comparison with those of Hawaii, for example. Satisfactory progress has been made during the past season in establishing the relation which the various species bear to one another and to their environment, and in securing a photographic record of their characteristic activities.

Studies on Sea-Water Bacteria and Other Subjects in the South Seas, by Charles B. Lipman.

Precipitation of Calcium Carbonate.

A new aspect of the subject of the origin of much of the mass of coral islands, or of calcareous beds in their vicinity, was introduced by Drew in 1911. He isolated an organism which he named *Bacterium calcis*, later renamed by Kellerman and Smith *Pseudomonas calcis*, which he claimed was responsible for the precipitation of the calcium carbonate in the calcareous muds underlying the waters surrounding calcareous reefs and coral islands in the Florida-West Indian region. This hypothesis for the explanation also of the oölitic deposits has been generally accepted by those concerned with the geology and biology of the regions in question.

In an attempt to determine whether or not similar causes for lime precipitation are extant in the tropical Pacific, the writer made an investigation of the bacterial flora of the sea-water surrounding certain reefs fringing the island of Tutuila in American Samoa and also of that in the open ocean 2 or 3 miles distant. This study resulted in the isolation of a number of sea-water bacteria and the test of them as regards ability to precipitate calcium carbonate. In a variety of tests it was not possible to obtain precipitation of calcium carbonate in sea-water alone, except to a very slight degree with one or two bacteria. Among the bacteria isolated, and which produced a slight precipitation of $CaCO_3$ in sea-water, was one which resembles and is probably identical with *P. calcis*. In a calcium-lactate sea-water medium the precipitation under consideration was found to occur readily and markedly, but about equally with all other organisms isolated.

Since Drew did not try to obtain precipitation of calcium carbonate in natural sea-water, the writer is led to the conclusion that his hypothesis is incorrect, or at least not proved, since calcium-malate sea-water which he used is an artificial medium, an analogue of which would probably not occur under natural conditions. The reason for the precipitation in the artificial medium can easily be explained on the basis of the chemistry of such culture solutions. The details of this study, presenting the several steps which led to the refutation of Drew's hypothesis, will be given in a forthcoming paper. An attempt will be made, however, to study the situation in the tropical Atlantic under the same conditions as those under which Drew worked, so that his results may be checked, and so that we may ascertain if the difference between the two environments can make possible the validity of the hypothesis tested for one region and not for another.

Number of Bacteria in the Sea-Water surrounding the Island of Tutuila.

Studies were made on the number of bacteria in the waters covering the Aua Reef and also of the waters 2 or 3 miles out to sea from the naval station of Tutuila. The number of organisms, as determined by plating out the waters on nitrate-peptone sea-water agar, were approximately 1,000 to 2,000 bacteria per cubic centimeter in the ocean-water from 2 to 3 miles out at sea, and from 70,000 to 100,000 bacteria per cubic centimeter in the water of the Aua region.

The variations in numbers occurred at different periods of sampling. The effect of shore conditions in shallow water is thus apparent, and was observed previously by Drew in the Bahamas.

The forms of bacteria, however, are not numerous in the tropical Pacific. In the case of the uncontaminated ocean-water, not over five or six different kinds of bacteria, so far as the medium in question is concerned, were found. In all cases, moreover, including both the reef-water and that out at sea, one dominant specimen of bacterium was always found in the medium in question, which developed most rapidly and produced large colonies on the plates. This organism has not yet been identified.

Rose Island Notes.

Studies were made on certain materials brought back by Mr. Mayor from his trip to Rose Island in the Samoan group. The soil from Rose Island, which is formed by the decomposition of highly calcareous material, resulting in turn from the disintegration of lithothamnium masses, contained an interesting bacterial flora. The number of bacteria in this soil is not nearly so great as in similar soil of greater age and under cultivation, but it appears now, though only incomplete studies have been made, that some interesting new forms of bacteria will be found. Some well-known old forms were encountered, among them *Azotobacter chroococcum*.

The surface crust of Rose Island, and of the atoll on which it is situated, consists largely of lithothamnium, but underlying the loose mass of lithothamnium is a more compact limestone having very much the appearance and (on a qualitative test) the composition of a dolomitized limestone. On a quantitative analysis of that substance, however, it was found to consist of 44.52 per cent calcium and only 6.98 per cent magnesium. This analysis shows that the material is not fully dolomitized, but is probably in process of being formed into dolomite.

The surface rock from Rose Island is a loose and light substance into which roots and decaying organic matter had penetrated. It was thought that that material might contain large quantities of phosphoric acid and therefore be valuable for fertilizer material. An analysis was therefore made of specimens of this substance, and it was found to contain 12.05 per cent of phosphoric acid. While this figure is very high for that kind of material, the quantity of phosphoric acid is not high enough to make it pay to work the deposits as a phosphate mine, especially considering the difficulties of transportation.

Studies on Sea-Water Phænogams.

With the object of determining whether the few rare species of flowering plants growing in sea-water may possess some key to the solution of the important physiological problems of the absorption of salts from the growth medium, it was determined to make a study of one of the interesting and remarkable plants found at the edges of the reefs in the harbor of Pago Pago. This plant, nearly related to *Halophila ovalis*, can be gathered at low tide from beneath the sea-water and coral sand which covers most of it. Analyses are now being made of that plant and of similar plants, which, it is hoped, may throw light on some important phases of plant physiology.

Experiments on the Rate of Growth of Sessile Marine Organisms other than Corals, by F. A. Potts.

The object of these experiments was the comparison of rates of growths and dates of sexual maturity in animals of temperate and tropical seas respectively. A body of facts has been accumulated for the former (*cf.* Orton, Proc.

Mar. Biol. Assn., vol. 12, 339–336, 1920), but the latter field, except in the case of corals, has not been touched previously.

Small rafts of various sizes, mostly of Oregon cedar, were attached singly and in series to buoys in the harbor of Pago Pago and examined constantly. The succession of animals settling and growing thereon was observed, and at definite intervals one of a series of rafts was removed to the laboratory to be photographed and preserved. Other experiments were with small cages, the sides of which were made of sheets of perforated zinc, with planks weighted so as to hang vertically, and with glass plates carried underneath small wooden rafts.

Rich growths of hydroids, compound tunicates, polyzoa, colonial serpulid worms, and barnacles were established very quickly on the under surface of the rafts. Within 3 weeks the wood was completely covered by the colonies. The wood-boring lamellibranch *Teredo* was invariably among the first colonists, and in less than a month the wood was riddled by its burrows.

The most definite results were obtained in the case of the goose-barnacle (*Lepas*), a valuable genus for comparison, since its species are scattered widely over the world. In 19 days after the rafts had been placed in the sea the ends were fringed with barnacles of a considerable size, producing *Nauplius* larvæ. After attaining sexual maturity, the growth-rate slows down, but in one case full size was nearly attained within a period of 50 days. Observations of the time required to attain sexual maturity were also made on *Teredo* (which produces larvæ within 24 days), the hydroid *Pennaria*, the compound tunicate *Leptoclinum*, and serpulid worms.

The rate of growth of colonies was best studied in cases like the serpulid worm *Filigrana* and in some Polyzoa.

A period from the middle of May to the end of July was available for continuous observation, but even this was seriously curtailed by heavy rains which caused great mortality among the animals growing on the rafts. The facts recorded must therefore appear scanty compared with those gathered by a resident observer in temperate regions, but the cases cited above show that in all probability some animals, like *Lepas* and *Teredo*, living in a constant temperature of from 26° to 30° C., grow at a considerably greater rate and become sexually mature very much earlier than their allies in northern waters; in others, like hydroids and colonial tunicates, the processes of growth and maturation do not seem to be greatly accelerated.

Marine Algæ and Terrestrial Plants of Tutuila, Samoa, by William A. Setchell.

The main object of my visit to the island of Tutuila (May 31 to July 28), was to make observations on, and collect specimens of, the incrusting and other species of marine algæ to be found on the coral reefs of the island, in order that their identity might be more thoroughly established than has been done previously. As intimately connected with this intention, it seemed best to attempt to collect and study all other marine algæ and to determine their relation, if any, to those of the reef, and the ecology of both.

Somewhat distinct from these objects, but as having a bearing on the general study of the island and its reefs, it seemed best to make such a reconnaissance of the land flora and of its ecologic relations, both general and special, as might be possible during the limited time of my stay. An attempt was made, therefore, to collect all species possible, to learn their Samoan names and uses, and particularly to determine the distribution of each species and to obtain the data for arranging them in their proper belts, formations, associations, etc. With the assistance of Sūtupe, a native of the village of Pago Pago, about 36 years of age, and apparently very well acquainted with the plants of the

island, about 700 plants were collected, and notes and studies made in connection with them. From these it seems possible to base reports which will cover the ground outlined in my statement of purposes.

Report on the Annelids of Puget Sound, Fiji, and Samoa, by A. L. Treadwell.

From February 13 to March 4, I studied at the Puget Sound station of the University of Washington at Friday Harbor. To Professor T. C. Frye, director of this station, I am greatly indebted for putting its resources at my disposal. The collecting was done in the immediate vicinity of Friday Harbor and at False Bay on the opposite side of the island. What are certainly new species were obtained in the genera *Lumbrinereis*, *Onuphis*, *Nainereis*, and *Eteone*, and a survey of the literature, as yet uncompleted, may show that others still unidentified are new. An account of these will appear in a later publication. The following notes refer to old species. *Autolytus varius* Treadwell was collected in the sacconereis stage, carrying eggs and larvæ, in the herring-trap at the shipyard; *Podarke pugettensis* Johnson was rare, 2 specimens only having been found in Newhall's lagoon; *Nereis virens* Sars, *N. vexillosa* Grube, *N. procera* Ehlers, and *N. agassizi* Ehlers were common in all the collections, as was *Nephthys cœca* Fabricius. The commonest annelid found was *Lumbrinereis zonata* Johnson, the other Leodicidæ found being a new species of *Onuphis* and of *Lumbrinereis*, with one specimen of *Onuphis* (*Northia*) *elegans* of Moore. *Glycera rugosa* Johnson and *Hemipodia borealis* Johnson were common, though not very abundant, in all localities. *Polydora californica* Treadwell was abundant in Newhall's Lagoon and in False Bay, and *Scolecolepis alaskensis* Treadwell occurred in the collections. Johnson described two species of *Cirratulus*—*C. cingulatus* and *C. robustus*. These were rare, but specimens corresponding to both species were found on Turn Island and at Minnesota Reef. For reasons which will be given in a later paper, these do not seem to me to be distinct species, and the name *cingulatus* has precedence.

Ammochares occidentalis Johnson occurred in considerable numbers at False Bay, and I found one specimen on the beach at Brown Island. Of the Terebellids, *Lanice heterobranchia* Johnson and *Thelepus crispus* Johnson were both abundant. It is easy to distinguish them in the living condition by the green color of the former and the red color of the latter. *Serpula columbiana* Johnson was found in rocks above low-water mark at the station reservation. Two species of *Capitella*, one being evidently Johnson's *C. zonata*, were common, and *Arenicola claperedii* Lev. was very abundant, especially in Newhall's Lagoon and in Boat Bay. Later work was in Suva, Fiji, from April 6 to May 4, and in Pago Pago, Samoa, from May 12 to June 22. In these localities my main study was on the Leodicidæ, having in mind a comparison between the Pacific members of this family and those of the West Indian region, which have been the subject of investigations under the auspices of the Carnegie Institution of Washington. Since the literature of the Pacific species was not available in the field, I have not attempted the identification of species and their description will appear in a later publication.

In Fiji, the research was limited to the immediate vicinity of Suva Harbor, the short length of our stay preventing any more extended explorations. In Suva Harbor the reefs on either side of the main entrance and at Rat Passage are relatively rather poor in annelids, but apparently the Leodicidæ are better represented than any other single family. The rocks near the outer margin of the reef are channeled by various boring echinoids, and contain many individuals of a rather large *Leodice*. Other large species were found under

loose rocks on the surface of the reef. The only one of the latter that was at all abundant was a slender, delicate species living in tubes, the tubes being composed of small stones loosely cemented together. An extremely common species was first regarded as a *Nicidion*, but a study of a more complete series showed that they are evidently very young individuals of *Leodice viridis*, the palolo. There is no record of the palolo swarming at Suva, and I got no well-developed individuals. From a comparison of these with specimens collected in Samoa, I am convinced that the identification is correct, and that, if it swarms at all in Suva, the numbers of individuals are too small for the swarming to attract attention. It seems to me possible that, because of unfavorable conditions, the animal may never reach sexual maturity on the inner parts of the reef, the population being kept up by migration in the trochophore stage from other localities.

In American Samoa a thorough study was made of the annelid fauna of the reefs in Pago Pago Harbor. Here, as in Suva, the coral rock is rather poor in annelida, but the Leodicidæ are represented by the greatest number of species. In this harbor, as in other parts of the islands, the mud-flats lie at the mouths of streams, where the dilution by fresh water prevents the growth of Polychætes, and a capitellid is usually the only genus represented, though some terebellids were collected at the upper end of Pago Pago Harbor. A *Lumbrinereis* and an *Arabella* were collected on the under side of stones from Utelei and Aua reef respectively. This is of interest, for these are characteristically mud-living forms, and their adaptation to this peculiar habitat is very unusual. Species of *Leodice*, *Lysidice*, *Nicidion*, *Stauronereis*, and *Aglaurides* were collected in the coral rocks, the first-named genus being the most abundant. Many of the species are identical with those collected in Suva, *L. viridis*, the palolo, being the commonest. These are found in all of the reefs, being more abundant in those regions where the annual swarming is most in evidence, though I found no locality where they were abundant enough to give rise to the enormous numbers found in the annual swarm. Since the larger individuals appear toward the outer margins of the reefs, I am of the opinion that the greater number of the animals live in the deeper parts of the reef, on the outer margin, where, on account of the surf, collecting is practically impossible. Toward the shore, the individuals become very small and undeveloped, though I could discover no other difference between these and the large ones. If our information about the swarming is correct, the eggs are all laid at the same time, and the individuals found in 1920 were hatched from eggs laid not later than November 1919. As stated above, of the Suva specimens, I question whether those nearer shore ever become sexually mature, because of the unfavorable environmental conditions.

A comparison in *L. viridis* was made between those collected at the spring tide in May and the corresponding tide of June. The latter were distinctly farther advanced toward sex maturity than the former, though in only a few cases were the eggs sufficiently mature to begin to show the green coloration. It should be remembered that the latest collecting was several months before the swarming, so that no very high degree of maturity was to be expected. Dr. Mayor, director of the expedition, kindly collected for me during the July spring tide, but found there was very little change in maturity over the condition occurring in June.

The reef at Aunuu village was fairly rich in annelids, the most abundant being a large species apparently identical with one collected at Suva. That at Leone was very poor, and the mud-flats inside the reefs are too abundantly supplied with fresh water to be favorable to annelid growth. The most characteristic mud-flat on the island is along the eastern shore of the lagoon near Nuuli, where a small *Marphysa* was found.

DEPARTMENT OF MERIDIAN ASTROMETRY.[1]

BENJAMIN BOSS, DIRECTOR.

The efforts of the Department during the past year have been mainly employed in completing the work on the San Luis observations and in preparing them for catalogue form, though considerable work has been devoted to the reduction of the Albany observations. Progress has also been registered in the determination of the systematic corrections to star catalogues in preparation for the general catalogue. In addition, a number of special researches have been carried on. Preparation for the future work of the Department has also called for a careful study of the problems involved.

A brief summary of the most salient landmarks in our progress follows.

ABSOLUTE MAGNITUDE.

A study of absolute stellar magnitudes is in progress. While definitive results have not been attained, some conclusions seem to be fairly well marked. When the frequency curves are drawn, the maximum for the giant stars is placed at $M = +0.75$, the bulk of giant stars lying between absolute magnitudes -1.5 to $+3.0$. But the elements of distance play an important rôle in determining the frequency curve, for with increase in the distance of the star it is evident that, in the main, only the brighter stars have been observed. If the absolute magnitudes of the giant stars are arranged in groups according to increasing distance, it becomes evident that in order to obtain an absolute magnitude of $+2.0$ for a star whose parallax is $0\overset{''}{.}006$, the apparent magnitude would have to be 8.1. As the parallaxes of but few stars of this magnitude have been obtained, and those mostly for dwarf stars, it would seem more probable that the mean absolute magnitude for a giant star is in the vicinity of $+1.2$, instead of $+0.75$ as given by the frequency curve. A peculiarity in the distribution of the observed giant stars among the types is the striking lack of such stars in the A and F classes. The frequency curves of the dwarf stars show well-defined maxima, increasingly positive, with progression in type from the B to the M class, following the results previously obtained by other investigators. It is interesting to note, however, that the dwarf phenomenon is distinctly apparent among the A-type stars.

DIURNAL TERM IN CLOCK-RATE.

In the preliminary reductions of the primary clock stars for clock corrections and rate, preparatory to deducing the final places of the primary clock stars, Mr. Varnum spared no efforts to insure the fundamental nature of the reductions. Where possible, the observations have been combined to eliminate the known systematic errors. For

[1]Address: Dudley Observatory, Albany, N. Y.

the preliminary reduction, only those series have been used where the clock correction could be determined from groups of stars 12 hours apart and where the clock-rate could be derived from successive transits of the same stars. Thus errors in right-ascension depending upon right-ascension and any existing diurnal effect are practically eliminated, as are also the assumed positions of the clock stars.

The series of observations used extend over periods of 24 to 130 hours, with a group of clock stars every 12 hours. In a large majority of cases there are also successive transits of a circumpolar star to effect a determination of the azimuth independent of the assumed right-ascension. This should insure a reasonable degree of freedom from systematic error and error in the assumed place. For the preliminary discussion, 347 series containing 4,652 observations were available.

After correcting the resultant clock corrections for a term in right-ascension dependent upon declination, they were collected in the order of right-ascension, and a preliminary value of the term in right-ascension depending upon right-ascension was determined. Applying this term, the observations were then collected in order of the local mean time of observation and a preliminary diurnal term was found. After correcting for the diurnal term, a preliminary term east *minus* west was formed. Three approximations were employed to deduce the final results.

The final terms in right-ascension dependent upon right-ascension are:

Albany..........	$-0\overset{s}{.}008$ sin R. A.	$+0\overset{s}{.}012$ cos R. A.	(corrn. to P. G. C.)
San Luis........	-0.008 sin R. A.	$+0.009$ cos R. A.	(corrn. to P. G. C.)

The diurnal term is:

$+0\overset{s}{.}0114$ sin M. T. $-0\overset{s}{.}0073$ cos M. T. (corrn. to obsd. Transits)

In order to test the reality of the diurnal term, a rough treatment was made of material obtained from the following catalogues: Greenwich Observations for 1907–8; Pulkova Series II, Vol. 20, 1894–6; Cape Fundamental Catalogue for 1900.

For Greenwich and Pulkova observed clock corrections were given. Those series were selected where there was a fair distribution of observations throughout 24 hours. The resultant diurnal terms are listed below.

Albany..........	$+0.0114$ sin M. T.	-0.0073 cos M. T.
Greenwich.......	$-$ .0058	$-$ .0129
Cape...........	$-$ .0054	$-$ .0069
Pulkova........	$-$ .0033	$-$ .0078

For Albany there is a well-marked maximum at 8 hours, for Greenwich at 13 to 14 hours, for Cape at 14 hours, and for Pulkova at 13 to 14 hours. This peculiarity suggested an effect depending upon longitude. The material was then arragned according to Greenwich mean time and further treated as a cosine term. The tabulated results give

Albany..........	$+0^s.0135$ cos (13^h	6^m	$-$G. M. T.)
Greenwich......	+0.0141 cos (13	37	$-$G. M. T.)
Cape...........	+0.0088 cos (13	19	$-$G. M. T.)
Pulkova........	+0.0084 cos (11	31	$-$G. M. T.)
Mean.......	+0.0102 cos (12	53	$-$G. M. T.)

The comparatively close agreement in the results raises the question whether the diurnal term may not be a function of the absolute instant of time and not merely of the local mean time. If the diurnal term of the Melbourne Observatory could be determined and should accord with the results already obtained, the subject would warrant an extensive investigation.

It might be remarked, in passing, that in the treatment of the Albany and San Luis observations for diurnal term, several combinations of results were employed. The corrections were combined according to observers, clamp, seasons, and years. Also, during the period 1907–1913, the Riefler clock ran unsealed, with no effective temperature control, while during the period 1915–1918 the clock was sealed and the temperature of the clock-room was practically constant. The diurnal term was evident, no matter what the arrangement might be; therefore there can be little doubt concerning the reality of the diurnal term. It only remains to determine the nature and cause of the variation.

PERSONALITY IN THE ESTIMATION OF TENTHS.

The investigation by Dr. Albrecht on personality in the estimation of tenths was undertaken with a view to its bearing upon the design of a special measuring instrument for which extensive use is contemplated. Information regarding a proper balance of speed and accuracy of measurement was sought.

Among the more general results obtained, it was found that personality in the estimation of tenths is a very definite thing, rendering it possible to apply corrections to the measures within certain limiting conditions. The nature of this form of personality was discussed for 23 observers, covering various intervals of time, in one case 39 years. It was established that the epoch is the important consideration in discussing a personal scale. Individual scales may vary, but the variation is gradual and generally progressive. The personal scale is essentially constant during short periods of time, generally for a few months. Fatigue during a continuous 5-hour period of observing produced no appreciable change. The zero tenth is almost universally favored, while no tenth is as generally neglected as the zero is favored. Most of the curves representing personal scales are essentially symmetrical with respect to 0.0 and 0.5, though a few show an unbalanced preference for or neglect of one or two of the tenths. Most observers have a definite tendency to estimate an index too close to the nearer of the two adjacent scale-rulings, the degree varying quantitatively

with the widths of the lines. When the scale-rulings and index have a width of 0.2 of a scale-interval, tenths can be read with practically no error. Among the most gratifying results obtained is the indication, derived from tests, that readers without previous experience in the estimation of tenths can acquire and retain a nearly true scale of tenths with a small amount of drill through the use of practice scales. On account of the influence which the widths of lines have upon the estimations, practice scales should always be similar to the scales employed in the regular work in respect to the comparative widths of lines and scale-interval.

STELLAR WAVE-LENGTHS.

Dr. Albrecht has continued his study of stellar wave-lengths. As a part of the more general program, the stellar wave-lengths have been computed for the individual lines which were employed for the determination of the radial velocities published in detail in Publications of the Lick Observatory, Vol. IX.

REDUCTION OF OBSERVATIONS.

Mr. Roy has found it advantageous to employ most of his efforts in supervising the reductions of the San Luis zenith distances, so little has been accomplished upon the Albany zenith distances. Mr. Varnum has devoted his time to the preliminary reductions of the Albany right-ascensions. The San Luis observations of the five observers have been collated on cards. Considerable time has been employed in applying the concluded systematic corrections for the separate observers to the final places as entered on the cards. One set of computations upon the precessions has been completed and the duplicate set is nearly finished. The computation of the secular variations is well under way. Many of the discordances among the observations have been investigated, but considerable work remains to be done to insure freedom from errors of computation and collection.

PREPARATIONS FOR THE GENERAL CATALOGUE.

The preparations for the general catalogue have continued under the supervision of Mr. Roy, the details of the comparison of catalogues with the standard system being largely performed by Mr. Jenkins and Miss Buffum. For the catalogues listed in the preceding annual report little remains to be done, with the exception of a definitive revision of the weights. Several catalogues have been added to the previously published list:

32. Karlsruhe..............	1890	0° to −8°.
33. Albany Zones..........	1900	−20° to −41°, −2° to +1°, and fundamental.
34. Cape..................	1900	Fundamental.
35. Königsberg............	1900	Largely zodiacal.
36. Königsberg............	1905	Fundamental.
37. Pulkova...............	1905	Fundamental.

Several requests for proper-motions have been received and they have been furnished when possible. As the reduction of the Albany observations has not sufficiently progressed to allow of their use without an undue amount of labor, with a great sacrifice in accuracy, proper-motions can be furnished only where recently published catalogues have contributed a sufficient amount of material to render the proper-motion determinate. Such proper-motions will be greatly strengthened when our observations are in condition for use.

SELECTION OF STANDARD COMPARISON STARS.

The selection of standard comparison stars for photographic plates of large area is essentially complete from pole to pole for the first 9 hours of right-ascension. In making up this list of stars the following desiderata have been kept in mind: (1) Uniform distribution, approximating one star per square degree; (2) uniform magnitude, as closely as possible within the limits 8.0 to 9.0 visual magnitudes; (3) well-determined positions; and (4) a fair representation of the general distribution of the stars in spectral type.

The Harvard magnitudes and spectral classifications have been used, over 40,000 of the stars listed in the first three volumes of the Revised Draper Catalogue being charted to form the basis of selection. In order to secure those stars whose positions and proper-motions are most determinate, preference was given to the stars to be contained in the Second General Catalogue, the Intermediary Standard Stars of the Astrographic Survey, and Gill's Zodiacal List. For those regions where these catalogues did not furnish stars, a selection was made based upon the data in the Yale Index of Stellar Positions.

The total number of stars listed for the first 9 hours of right-ascension is 15,442, 87 per cent of which (as shown in table 1) lie between the limits 8.0 and 9.0 visual magnitude and 94 per cent between 7.8 and 9.2, a range of only 1.5 magnitudes.

TABLE 1.—*Distribution in magnitude.*

Mag.	No.	Mag.	No.
7.2	16	8.0– 9.0	13,498
7.3	30		
7.4	111	9.1	292
7.5	106	9.2	277
7.6	156	9.3	212
7.7	197	9.4	62
7.8	259	9.5	1
7.9	225		
>M8.0	1100 7 p.ct.	<M9.0	844 6 p.ct.
>M7.8	616 4 p.ct.	<M9.2	275 2 p.ct.

Table 2 shows the distribution of these stars in spectral type. The representation of the distribution of the stars in general is good, especially when it is considered that there are comparatively few stars of the B class as faint as 8.0 magnitude and that the stars of the G and K classes are scattered more uniformly over the sky than those of the A class.

TABLE 2.—*Distribution in spectral types.*

Class.	No.	Class.	No.	Class.	No.
Oe5	2	A3	440	K2	927
B0	22	5	418	5	696
2	11	F0	838	Ma	156
3	23	2	503	b	42
5	46	5	1147	c	3
8	215	8	928	Nb	1
9	519	G0	1182	R3	2
A0	1812	5	2006	5	1
2	887	K0	2615	....	....

Dr. Wilson, who has been engaged on this work, has started a card catalogue of the stars selected, upon which observed positions and other data concerning the stars will be entered.

SEARCH FOR OBSERVING STATION.

The climatic conditions at Albany are unfavorable for any program of observations requiring continuity of effort over the entire year, as the winters are apt to be very cloudy, and clear days are accompanied by severe temperature.

As already reported, a thorough examination of weather conditions indicated that good seeing might be expected in the South Atlantic States and in the Southwestern States.

The Director, accompanied by Dr. Albrecht, spent the better part of 3 months in the fall examining the plateau in the South Atlantic States extending from the Coastal Plain on the east to the mountains on the west. The elevation in general varied from 500 to 800 feet. The ground is somewhat rolling and is largely under cultivation. The first part of the expedition was confined to a region lying from 75 to 100 miles east of the mountains, and extending from Greensboro, North Carolina, to Atlanta, Georgia, while the second part dealt with that part of the plateau lying close to the Coastal Plain. As a result of the tests carried on at 10 stations, it appears that the best conditions are obtainable in the region lying 75 to 100 miles east of the mountains.

A test of observing conditions in the Southwestern States is under way, and a fuller report will be made upon its completion.

STAFF.

The Director spent a portion of the year exploring for a suitable observing station in a region of the Southeastern United States promising to offer favorable conditions for observing. He has also devoted considerable attention to the future plans of the Department and to special investigations. Dr. Sebastian Albrecht accompanied the Director on his southern expedition, and has completed an investigation on personality in the estimation of tenths, besides continuing his investigation of standards of wave-length. Mr. Sherwood B. Grant resumed his duties after leaving the Navy and has been engaged on various reductions. Mr. Heroy Jenkins continued the derivation of systematic corrections to star catalogues. Mr. Harry Raymond has been occupied with many departments of the work. Mr. Arthur J. Roy has been mainly engaged in preparation of the San Luis catalogue and was in charge of the Department during the absence of the Director. Mr. William B. Varnum has continued to supervise the reduction of the right-ascensions of the Albany observations and has devoted considerable time to the investigation of an interesting phenomenon developing from the study of clock-rates. Dr. Ralph E. Wilson has been employed on a selection of comparison stars to be used in connection with the photographic determination of star positions. Miss Alice M. Fuller has continued as secretary of the Department.

The computing staff has been engaged on the multifarious operations involved in the reduction of the observations. It has consisted of Miss Marian F. Benjamin, Mrs. Lillian F. Blanchard, Miss Grace I. Buffum, Mrs. Livia C. Clark, Miss Mabel I. Doran, Miss Isabella Lange, Miss Marie Lange, Miss Frances L. MacNeill, and Miss Helen M. MacNeill. The Misses Mabel I. Doran and Helen MacNeill resigned on June 1 and August 1 respectively.

MOUNT WILSON OBSERVATORY.

GEORGE E. HALE, DIRECTOR.

SUMMARY OF THE YEAR'S WORK.

The 100-inch Hooker telescope, yielding results that are of service in all departments of the Observatory's work, has remained a center of interest throughout the year. In light-gathering power, in the photographic registration of minute details of structure, and in the separation and measurement, by Michelson's interference method, of double stars previously unresolved, this instrument has responded admirably to a wide variety of tests. Through its aid we have been enabled to carry our researches into new and profitable fields, thus considerably enlarging our research program. Before fixing the details of this program, it has seemed advisable to determine in what ways the capacity of the telescope could be most fully utilized, and for this reason much attention has been given to experiments with promising accessory apparatus and methods.

Altogether the most significant of the auxiliaries thus developed is Michelson's interferometer, which promises to play an important part in the future of sidereal astronomy. Its possibilities in this field were clearly foreseen and fully described by Michelson in 1890, and one of them was successfully tested by him in his measurement of the satellites of Jupiter in the following year. The fact that no astronomical applications of the method have since been made is not easily explained. Astronomers acquainted with the extreme sensitiveness of the interferometer, and constantly hampered by atmospheric disturbances, have naturally feared that differences in optical path would obliterate the fringes. But it turns out that they can be clearly observed with large apertures even when the seeing is poor.

A crucial test was made September 18, 1919, when Professor Michelson, at the first trial on Altair, had no difficulty in seeing the fringes with the full aperture of the 60-inch and 100-inch telescopes. The essence of the method lies in the use of two slits, symmetrically placed on either side of the axis of the telescope, and so mounted in a rotating support that their distance apart can be varied. As the mirror is otherwise covered, the only light entering into the focal image is that which passes through the slits. The conditions are thus precisely analogous to those of Fizeau's classical experiment, in which two pencils of light, derived from a single point-source, are brought to interference. Observed with a high-power eyepiece (2,000 to 10,000 diameters) the fringes appear as sharp, narrow lines on a fluctuating background. In a case like that of the close double star Capella, the components of which, about 0".05 apart, are not visible in any telescope, there are

two independent sets of fringes, one due to each star. On rotating the disk carrying the slits, the visibility of the fringes is seen to vary with the position angle. When the line joining the slits corresponds with the line joining the stars, the slits are separated until the fringes of one set fall exactly between those of the other, causing minimum visibility, or complete disappearance if the two stars are of equal brightness. The distance between the slits then permits the angular distance between the two stars to be computed with a precision greatly superior to that attained in the micrometric measurement of wide binaries. As an indication of this precision, it may be added that the greatest difference between the observed and calculated positions of the components of Capella, as determined by Mr. Anderson, is four hundred-thousandths of a second of arc. An account of the method describing the technique developed by Mr. Anderson for the measurement of both position angle and distance may be found on page 252. It is hoped that through a cooperative plan of observation, in which other observatories will take part, a large number of close binaries may be measured by the interferometer.

The simple use of two slits permits the theoretical resolving power of the Hooker telescope to be more than doubled under ordinary atmospheric conditions, and this result can be still further improved by attaching a large interferometer to the upper end of the telescope tube. An instrument of this sort, in which two plane mirrors, used instead of slits in combination with the 100-inch mirror, can be separated to a distance of 20 feet, has been built in our shop and tested on stars by Professor Michelson. The sharpness of the fringes observed with this enormous resolving power, which corresponds with the theoretical resolution of a telescope of about 40 feet aperture, indicates that atmospheric difficulties would not be likely to stand in the way of a much greater extension of the method. It remains to be seen whether it will prove feasible to accomplish Professor Michelson's desire to measure the angular diameter of a star (p. 250).

The truly extraordinary precision of measurement attained in the case of Capella naturally raises the question whether a comparable advance can be accomplished in the measurement of stars several minutes of arc apart. If this were feasible, the determination of parallaxes and proper motions might be greatly improved, and it might become possible to measure the displacement of a star caused by the gravitational field of Jupiter (Einstein effect). Professor Michelson has designed several forms of interferometer for this purpose, and one of them will soon be tested with the Hooker telescope. It is feared, however, that atmospheric disturbances, which would differ along the optical paths of the stars several minutes apart, may prevent the fringes from being observed.

Professor Michelson's work as a Research Associate of the Observatory will be continued and extended in various directions. In addition to his investigations on the astronomical applications of the interferometer, he has undertaken a new determination of the velocity of light by an improved method, which promises results of the highest accuracy. Preliminary tests made this summer over a distance of about 4 miles were so satisfactory that a range of 16 miles is now being tried, and it is hoped that it may prove feasible to use in the final work a still greater distance between stations (p. 253).

The area of the 100-inch mirror is about 2.8 times that of the 60-inch, and the Hooker telescope, under perfect atmospheric conditions, should theoretically reach stars about a magnitude fainter than we have been able to observe with the smaller instrument. This advantage has been fully attained in spectrographic observations under good conditions, thus permitting an important extension of our investigations of stellar spectra (p. 245). To show that an equal gain can be secured in direct photography, a series of comparative photometric tests has been made. These indicate that with seeing 6 on a scale of 10, stars nine-tenths of a magnitude fainter than those reached by the 60-inch can be photographed with the Hooker telescope during the same exposure-time. Moreover, the details of the moon's surface and the minute structure of nebulæ are much better shown with the larger instrument. Thus the most exacting and rigorous comparative tests, made simultaneously under identical atmospheric conditions, using plates from the same box, developed in the same tray, prove conclusively that the Hooker telescope has met our highest expectations. (p. 230).

The increased light-gathering power of the new instrument should add several hundreds of millions of stars to those already known. For certain classes of work, a further advantage can be attained by means of a simple device due to Mr. Shapley, who mounts a converging lens system a short distance in front of the photographic plate, thus concentrating the starlight in a smaller "tremor-disk" through a virtual reduction in the focal length of the telescope. The gain in light-gathering power over the 60-inch telescope used without this device is more than two magnitudes. While the field is necessarily limited through the interposition of the lens, this method has already proved its value in the investigation of star-clusters and nebulæ (p. 243). Another useful device for the study of the faint stars in crowded clusters is a large prism, mounted before the plate at the 134-foot Cassegrain focus (p. 242).

In this connection mention should be made of the visit of Professor Wright, who brought his slitless quartz spectrograph from the Lick Observatory in June in order to try it at the Newtonian focus of the

Hooker telescope. Excellent preliminary results were obtained, and it is hoped that he may be able to continue this work at some time in the near future.

The 100-inch telescope affords an exceptional opportunity for measuring the radiation of faint stars and of determining the spectral-energy curves of brighter ones. Dr. Abbot's long experience with the bolometer especially qualifies him for this work, which he will undertake as soon as his other duties permit. Meanwhile, the problem has been approached from a different direction with the aid of a thalofide cell, a new device for the measurement of radiation in which the sensitive substance, fused on a quartz disk and mounted in an evacuated tube, is composed of thallium, oxygen, and sulphur. The maximum sensitiveness of this cell, which makes it especially useful for certain observations, is at 10,000 angstroms. The preliminary tests made by Messrs. Shapley and Benioff with the 100-inch telescope are promising and the work will be continued with improved instrumental arrangements.

In connection with the experiments made last year by Messrs. Anderson and Babcock on the polarization of the light of the sky by day and night, an extremely sensitive means of detecting very slight traces of polarized light was developed. This device is being used with the Hooker telescope by Mr. Hubble in an attempt to determine whether the light of certain nebulæ shows any indication of polarization.

Finally, although no new instrumental accessory has been required for the purpose, a word may be added regarding the striking phenomena rendered visible on the moon's surface by the aid of the stereoscope. The very sharp lunar photographs made at the 134-foot focus of the Hooker telescope by Mr. Pease serve admirably for this purpose when pairs representing the same phase, but differing in libration, are combined. The distinct appearance of relief thus brought out should aid materially in the solution of lunar problems.

Other additions to the equipment of the Hooker telescope are in prospect, and the development of this instrument has already advanced so far that we are now able to complete the details of our general research program, some of the chief elements of which were indicated in the last annual report. While considering the most promising lines of attack on stars and nebulæ, the possibilities of the solar and laboratory work have been re-examined, with the object of perfecting a homogeneous and well-balanced general scheme. In this connection the completion of the remodeled Snow telescope and its accessories for work with the Fabry-Pérot interferometer, and the addition of several important instruments to our laboratory equipment, have been essential factors.

Full details of the work of the year may be found in the body of this report, but the chief investigations in progress may be briefly summarized here. Of exceptional current interest is the bearing of the solar

wave-length determinations of Messrs. St. John and Babcock on the generalized theory of relativity. It will be recalled that the careful investigations of Mr. St. John have failed to show a systematic shift of solar lines toward the red of the magnitude predicted by Einstein. Evershed has also failed to find the desired displacement, but the importance of the question is so great that no pains should be spared in settling it beyond the peradventure of a doubt. For this reason Messrs. St. John and Babcock have renewed their attack with improved apparatus, involving many refinements of procedure overlooked by less careful spectroscopists, some of whom have found no difficulty in confirming Einstein's prediction. Exceptional weight will certainly be deserved by conclusions based upon the admirable methods described in this report, in which direct spectroscopic determinations of wave-length are checked by wholly independent measures obtained with the aid of a Fabry-Pérot interferometer (pp. 259, 260).

The measured displacement of stars photographed near the sun by the British observers during the total solar eclipse of May 29, 1919, are of such precision, and in such close correspondence with the demands of the theory of relativity, that the validity of the conclusions based upon them does not appear open to question. Confirmatory evidence of the same kind is much to be desired, however, and for this reason it is hoped that the Michelson interferometer may prove to be suitable for the measurement of the small displacement of stars by Jupiter called for by the theory. The difficulties arising from atmospheric disturbances may perhaps prove insuperable, but a serious effort will be made to apply the method.

The solar activity continued to decline during 1919, and at present the sun is remarkably free of spots. The consequent absence of disturbing local fields has permitted us to renew our study of the sun's general magnetic field, and Mr. Ellerman has taken a large number of photographs of spectra for this purpose during the summer of 1920. These will usefully supplement the plates secured during a favorable interval in 1916, which Mr. van Maanen's recent measures show to confirm within narrow limits the period of 31.52 days found for the rotation of the sun's magnetic axis in 1914. No high-latitude spots have yet appeared as forerunners of the next cycle, and we still await the opportunity to determine whether the reversal of magnetic polarity observed at the last minimum is to be confirmed (p. 222).

At Mr. Abbot's request, Mr. Nicholson has undertaken a comparison of the variations in area of the dark hydrogen flocculi (prominences photographed in projection on the sun) with the variations of the solar constant of radiation. Clayton's recent success in basing weather predictions on changes in the solar radiation directs renewed attention to the importance of finding a corresponding correlation of these short-period fluctuations with other classes of solar phenomena, and Mr. Nicholson will give special attention to this subject.

The Mount Wilson photographic map of the sun-spot spectrum, on a scale of 1 centimeter to the angstrom, has been completed by Mr. Ellerman for the region λ3900–λ6600. This scale, supplemented by the use of a Nicol prism and compound quarter-wave plate over the slit of the 75-foot spectrograph of the 150-foot tower telescope, suffices to separate the components and to show the polarization phenomena of many lines affected by the magnetic field. The numerous band lines and the changes of line intensity due to the reduced temperature in spots are also well shown. The map should prove of service in solar and laboratory investigations and in the study of red stars under high dispersion (p. 224).

The infra-red region of the solar spectrum, rendered accessible by the use of plates sensitized with dicyanin, has been photographed by Mr. Brackett as far as λ9900. The great majority of the 550 lines measured are of terrestrial origin, but through the detection of their displacements produced by the solar rotation, Mr. Brackett has identified about 50 solar lines (p. 229).

Our investigations of nebulæ have been considerably extended, and now embrace a wide variety of objects. Mr. Pease and Mr. Duncan have continued to photograph nebulæ of interest with the 60-inch and 100-inch telescopes, with special reference to proper motions and the problem of rotation in spirals (p. 232).

Provisional measures by Mr. van Maanen of 32 points in the spiral nebula M 33 indicate the presence of internal motions analogous to those previously found in the case of M 101, namely, an outward motion along the arms of the spiral. The number of points for which this general result does not hold is so small that it may be accepted as the characteristic feature of the motion. The photographs compared were both taken with the 60-inch reflector, one by Mr. Ritchey 10 years ago, the other by Mr. Duncan in August. The mean motion of the nebular points for the 10-years' interval, relative to the comparison stars, is about 0″.2, which is of the same order as that found in the case of M 101.

Mr. Hubble has made a study of the three known variable nebulæ, one of which (N. G. C. 6729) has shown decided changes within a single day. These remarkable objects do not appear to give indications of actual motion; from the available evidence their variation seems to be the result of irregular brightening and obscuration of a nebulous background. Mr. Hubble has also taken numerous long-exposure photographs with the large field of the 10-inch photographic refractor and a camera of 6 inches focus for the purpose of determining the distribution of the dark markings on the sky. The results suggest that they lie on a plane inclined at a small angle with the galactic plane, and coinciding with that of the local cluster of B stars (pp. 233–235).

Measures of the color-indices of Herschel's nebulous stars by Messrs. Seares and Hubble show that these interesting objects are much redder than ordinary stars of the same spectral type, presumably because of the scattering of their light by their nebulous surroundings, though other explanations may be suggested (p. 236). Another investigation bearing on the nature of spiral nebulæ and the problem of "island universes" has also been made by Mr. Seares. This consists of a determination of the surface brightness of the galactic system as it would appear from a distant point in the direction of the galactic pole. It turns out that the surface brightness of all known spirals is greater than that of the Galaxy; in some of the brighter ones the proportion is about 100 to 1. Thus, if these objects are really systems of stars, they must differ greatly from our own system in the relation of stellar density to linear dimensions (p. 240).

Some years agoProfessor Kapteyn derived a first approximation for the laws of stellar luminosity and density. In the meantime, a large amount of material has been accumulated and much work has been done in the direction of perfecting our knowledge of these laws, which are fundamental as an expression of the constitution of the galactic system. Much still remains to be done before a complete solution can be given; but a second approximation has now been finished by Professor Kapteyn, Research Associate of the Observatory, with the collaboration of Dr. van Rhijn. It is still necessary to treat all spectral types together and to regard the system as symmetrical about an axis, with the sun at or near the center. The luminosity curve has now been carried well past the maximum, which corresponds to an intrinsic brightness 2.9 magnitudes fainter than that of the sun. A Gaussian error curve represents the distribution of the luminosities with an extraordinary precision over a range of more than 18 magnitudes. Professor Kapteyn's investigation has made it possible to give for the first time an indication of the variation of stellar density with galactic latitude, as well as with distance. The results are most reliable in the direction of the poles of the Galaxy. In this direction the density falls to 0.01 of its value near the sun at a distance of about 1,200 parsecs, while in the galactic plane this value occurs at a distance of about 9,000 parsecs. The curves of equal density are much flattened and emphasize anew the structural importance of the Galaxy. A full account of this investigation appears in Mount Wilson Contribution No. 188 (p. 254).

Planetary nebulæ, especially on account of the resemblance of their spectra to those of Novæ and variable stars (p. 247), are of great interest in the study of stellar evolution. The extensive investigations of these objects at the Lick Observatory render another general attack unnecessary, but there are certain particulars in which we may usefully supplement the work at Mount Hamilton. Mr. van Maanen's meas-

ures of the parallax of the central stars of planetaries, indicating their faint absolute magnitudes and showing their distances to be of the same order as those of Novæ, are cases in point (p. 237). Including five of these objects, 22 new trigonometrical parallaxes have been completed this year, making 122 in all. A few spiral nebulæ are included in the list, though not with the expectation of finding measurable parallaxes.

The magnitudes of all stars recorded by the 60-inch reflector in exposures of 15 minutes on Kapteyn's Selected Areas Nos. 1 to 139 have been completely measured and reduced under the direction of Mr. Seares. The results are being prepared for publication in connection with Professor Kapteyn's magnitude determinations for the same areas on plates of longer exposure, the first large installment of which has been received from Groningen (p. 239).

The continuation of Mr. Shapley's investigations of star-clusters has added further arguments in support of his view that the galactic system is very much larger than was formerly supposed from considerations based on the brighter stars. If his conclusions are correct, the brightest stars in globular clusters must be giants; if the other view is sound, they must be dwarfs.

The question, on which evidence had already been secured from a study of the spectra of certain of the brighter stars, photographed by Mr. Pease with a slit spectrograph, has been further tested by the aid of the device already mentioned—a large prism, of small angle, mounted near the 134-foot focus of the Hooker telescope. The continuous spectra of the stars in clusters, from λ3800 to λ7500, are thus photographed on Ilford panchromatic plates, on which well-known giants and dwarfs, of determined spectral type, are also photographed for comparison. The distribution of light in the spectra of the brightest cluster-stars corresponds with that of known giants of the same spectral type as the cluster-stars, and is characteristically different from that of known dwarfs (p. 242).

The fainter stars in clusters are hardly less interesting, and the use of an intensifying lens with the Hooker telescope has enabled Mr. Shapley to photograph much fainter objects than could be reached formerly. He has also continued his studies of globular and open clusters, analyzed the characteristics of 1,152 giant stars in 9 clusters, and determined the total intrinsic luminosities of 40 globular clusters, which he finds, on the average, to give 275,000 times as much light as the sun.

Mr. Shapley's investigation of the faint globular cluster M 72 has revealed the presence of many variables, 26 of which have been studied, giving the light-curves and periods characteristic of Cepheids of the cluster type, and indicating that the distance of this very remote cluster is 83,000 light years. Assuming the validity of Eddington's theory of the radiative equilibrium of a giant star, he has derived theoretically a

period-luminosity law for Cepheids, and concludes that the average heat content per unit mass is nearly identical for all of these stars having periods longer than three days.

The continuation of the systematic investigations of stellar spectra by Messrs. Adams, Joy, Merrill, Sanford, and Strömberg, assisted during the past year by Messrs. Duncan and Hoge, has yielded 135 new determinations of (constant) radial velocity and the orbits of five new spectroscopic binaries. Both the 60-inch and 100-inch telescopes have been employed, the former chiefly for the absolute magnitudes of stars brighter than the eighth magnitude, the latter for the study of fainter stars, including those with very large proper motions, Md stars, faint Cepheids, Algol variables, Novæ, and miscellaneous objects (p. 245).

The reductions of Mr. Adams's determinations of stellar luminosity and parallax have been finished during the year, and the complete tables will be published within a few weeks. The spectroscopic method of measuring parallaxes has proved increasingly satisfactory, and the detailed comparison of the results with the best trigonometric parallaxes indicates a very high order of precision. The tables provide data for many interesting discussions, some of which are also in preparation for publication.

Much attention has been devoted by Mr. Adams and his associates to the spectra of temporary stars, and many new and interesting phenomena have been observed. In Nova Lyræ, for example, the displacements of the two components of the hydrogen lines on February 5 were in the ratio of 2 to 1, while the oxygen and nitrogen lines were shifted by the larger of these values. Displacement ratios of 3 to 2 and 2 to 1 were noted in the last annual report for the components of the hydrogen lines in other Novæ, and the discovery of a similar phenomenon in the spectrum of the variable T Pyxidis may prove to be of significance in the development of the theory of temporary stars. As the spectrum of T Pyxidis in April also showed other close resemblances to that of a Nova at an intermediate stage, the question of possible relationship will be closely pursued (p. 247).

The interesting phenomena observed in the spectrum of *o* Ceti (p. 249), and the discovery by Mr. Merrill of the characteristic nebular lines in the spectrum of R Aquarii, emphasize the necessity of directing renewed attention to the spectra of variable stars in all stages of brightness. Nebulium has not been founa previously in any stellar spectra except those of Novæ, and it is very important that many other Md stars be observed near minimum, when the nebular lines, which in R Aquarii do not appear to change in brightness, should be most easily detected. The Hooker telescope affords the necessary light-gathering power for such observations, which will be included in Mr. Merrill's general investigation of the Md stars. The radial velocities of 46 of these stars have now been determined, making a total of 90 thus far

known. The mean systematic difference between the radial velocities, as measured with the bright and dark lines, is about −20 km.; and the average motion given by the bright lines, if truly representative, is the greatest of any class of stars and does not differ materially from that of the planetary nebulæ. This coincidence, and the close resemblance of the spectra of planetaries with that of R Aquarii near minimum, are suggestions that will not be overlooked in future work (p. 249).

Turning now to the Pasadena laboratory, mention should be made of several important additions to its equipment. These include a 500-k. w. direct-current generator set, which greatly increases the range of our investigations with the arc, electric furnace, and other light-sources calling for heavy current; a special solenoid magnet for the Zeeman effect, designed to carry a current of 4,000 amperes, now nearly ready for trial; a new electric furnace for the study of emission and absorption spectra at high temperatures; a 2-inch concave grating mounted for use as an auxiliary dispersion piece for work with the Fabry-Pérot interferometer; and a large condenser and other apparatus for the production of explosive discharges through fine wires.

Mr. King's electric furnace investigations have been extended to include the rich spectra of several of the rare-earth metals and the infrared region of iron and manganese. The cyanogen band at λ3883 has also been photographed in absorption for measurement in connection with Mr. St. John's work on the Einstein effect in the sun. As the question has been raised whether the sensitive high-temperature lines of the furnace require electrical conditions rather than high temperature alone, for their production, the new 500-k. w. generator has been employed in testing this point. Several different means were adopted to maintain the high temperature and at the same time to reduce or completely eliminate the potential difference, and all were alike in indicating that the low potential differences involved are without effect on the spectrum (p. 258).

With the object of imitating the spectroscopic phenomena which must accompany the fall of a meteorite into the sun, Mr. Anderson has exploded fine wires by the discharge of a large condenser. The resulting light-source, attaining a brightness more than one hundred times greater than that of the sun and a black-body temperature of some 20,000° C., is of great interest spectroscopically. The absence of the principal enhanced lines, and the reversal of the spectrum far into the red, indicate the desirability of pushing this investigation further (p. 262).

The same condenser has been used by Messrs. Anderson and Babcock to produce brilliant and very violent sparks for spectroscopic study. The extreme characteristics of the spark spectra of iron, titanium, chromium, and nickel have thus been determined for the region λ3000–λ7200 (p. 262).

The measurement of over 600 standards of wave-length in the spectrum of iron has been completed by Mr. Babcock with the Fabry-Pérot interferometer for the region λ3370–λ6750, and the work is being carried toward longer and shorter wave-lengths. Mr. St. John has covered the same region with the higher dispersion of a long-focus grating spectrograph, which permits the wave-lengths of a much greater number of lines to be measured. The results will be published together, as the errors of these two methods are complementary. It is expected that the excellent agreement of the results will help to eliminate the difficulties that have delayed the adoption of international standards of wave-length. Several American physicists are arranging to cooperate with the international committee, of which Mr. St. John is chairman, and a large number of wave-length determinations will be made by both methods (pp. 228, 259, 260).

The measurement of solar wave-lengths with the highest precision is an operation demanding the most rigorous precautions, especially in view of the errors ordinarily involved in the comparison of two light-sources. For this reason the use of four different methods of observation (p. 261), and especially the pains that are being devoted to fixing the exact positions of telluric and iodine standards for comparison with solar lines, are of special importance. Not only the Einstein effect, but many other questions, are in the balance, and extensive laboratory investigations are necessary in dealing with them. Thus the Fabry-Pérot interferometer is being employed to measure the wave-lengths of lanthanum, barium, calcium, cerium, and strontium lines, and displacements caused by pressure and by pole-effect in the arc are being determined with the highest possible precision (p. 261).

Other laboratory investigations have included the determination of the wave-lengths of oxygen and nitrogen lines given by metallic sparks in the red and infra-red (p. 260), photographic observations of the spectra of condenser discharges in high vacua (p. 263), and various miscellaneous studies.

Construction work has been limited chiefly to the erection of a wing of the Pasadena laboratory to contain the 500-k. w. generator and its switchboard; a large underground tank for the cooling system of the new solenoid magnet; the completion of the observing platforms for observers at the principal and Cassegrain foci of the Hooker telescope; installation of the constant-temperature control system for the 100-inch mirror; and the various additions to instrumental equipment already mentioned. The Hooker telescope is now essentially complete, but work on its accessory instruments will be continued as long as new and promising devices are in view.

STAFF.

The Director, in addition to his general duties, has devoted much time to the study of sun-spot hypotheses and other solar problems. Dr. Walter S. Adams, Assistant Director, has continued his investigations in stellar spectroscopy. Professor Frederick H. Seares, superintendent of the Computing Division and editor of the Observatory publications, has carried forward his stellar researches and his work on the general magnetic field of the sun. Dr. Arthur S. King, superintendent of the Physical Laboratory, has devoted most of his time to investigations with the electric furnace. Dr. Charles E. St. John has continued his studies of the solar rotation and the wave-lengths of lines in the spectra of Venus and the sun. Dr. J. A. Anderson has applied the Michelson interferometer to the measurement of Capella, studied the spectra of explosive electric discharges, and continued his tests of the ruling-machine with Mr. Jacomini. Dr. Harlow Shapley has pushed forward his investigations of star-clusters, variable stars, and other sidereal problems. Professor G. W. Ritchey gave up his connection with the Observatory in October. Mr. Harold D. Babcock has given his chief attention to his investigations of solar and standard wave-lengths. Mr. Francis G. Pease has carried on his work of instrumental design and his photographic observations of the moon and nebulæ, and has assisted Professor Michelson in his tests of the interferometer and the velocity-of-light apparatus. Dr. Paul W. Merrill studied the spectra of the long-period variable stars and spent part of his time in laboratory work. Mr. Ferdinand Ellerman has taken part in the solar observations and served as Observatory photographer. Dr. Adriaan van Maanen has devoted most of his time to the determination of trigonometric parallaxes and proper motions, and has made additional measures of the general magnetic field of the sun. Professor Alfred H. Joy, recently appointed secretary of the Observatory, has been engaged chiefly in stellar spectroscopic investigations. Dr. John C. Duncan, who joined the staff in June, has made photographic observations of nebulæ and taken part in the stellar spectroscopic work. Dr. Seth B. Nicholson has continued his observations of the sun and Venus, and his calculations of the orbit of the Ninth Satellite of Jupiter. Dr. Gustav Strömberg has continued his work on absolute magnitudes and spectroscopic parallaxes. Dr. R. F. Sanford has spent most of his time in stellar spectroscopic investigations. Mr. Edwin P. Hubble, who joined the staff in September, has devoted his entire attention to investigations of nebulæ. Mr. Frederick S. Brackett, who resigned from the staff on August 31 to continue his studies at Johns Hopkins University, has engaged in solar spectroscopic work. Mr. W. P. Hoge, night assistant with the 60-inch telescope, has taken part in the stellar spectroscopic observations. Mr. Milton Humason, night assistant,

has made photographic and stellar spectroscopic observations with the 10-inch telescope. Mr. Edison Hoge, who joined the staff in December as successor to Mr. Clarence Henshaw, has taken part in the solar observations and served as assistant photographer. Mr. Hugo Benioff has assisted during the summer in the solar observations and experimented with the thalofide cell. Mr. Sinclair Smith has been part-time assistant in the Pasadena laboratory throughout the year.

Professor J. C. Kapteyn, Research Associate of the Observatory, has continued his work in Groningen. Professor A. A. Michelson, who was appointed Research Associate last year, has conducted investigations at Mount Wilson on the application of interference methods in astronomy and on the velocity of light. Professor W. H. Wright, of the Lick Observatory, spent 10 days on Mount Wilson in June, photographing the spectra of gaseous nebulæ with his quartz spectrograph, attached to the 100-inch telescope.

Of the staff of the Computing Division, Miss Ware and Miss Miller have continued to assist Dr. St. John. Miss Burwell, Miss Brayton, Miss Hubbard (resigned August 1), and Miss Shumway have been engaged with the investigations in stellar spectroscopy. Miss Richmond, Miss Joyner, Miss Ritchie (resigned April 1), and Miss Mayberry have assisted Mr. Seares and Mr. Shapley. Miss Wolfe (resigned August 1) continued with the work on the sun's general magnetic field and on trigonometric parallaxes, in which she has been succeeded temporarily by Mrs. Magnusen, while Miss Keener has given her time to measures and reductions connected with the work of the Physical Laboratory. Miss Connor has remained in charge of the library and has assisted with the editorial work.

Mrs. Harlow Shapley, volunteer assistant, has collaborated with Dr. Shapley in his stellar investigations. Miss Edna Carter, professor of physics at Vassar College, served as volunteer assistant in the Physical Laboratory during the summer, where she investigated the spectrum of the electric discharge in high vacuum ("hot spark").

Dr. Charles G. Abbot and Mr. L. B. Aldrich continued the work of the Smithsonian Astrophysical Observatory on Mount Wilson during the summer.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

INSTRUMENTS.

The adaptation of the interferometer to the Snow telescope and spectrographic equipment has been completed. Recent tests have shown that the interferometer with quartz plates and invar étalons, surrounded by a water-jacket, can be successfully used with the full aperture (2 feet) of the Snow telescope. A definite portion of the beam is filtered through a 4-inch column of water, and the transmitted area

is again limited by the diaphragm of the interferometer. Highly reflecting surfaces protect the interferometer from all unused portions of the beam. Under these circumstances the slight change in thickness during a series of observations is of the same order as when artificial light sources are observed under the best laboratory conditions.

SOLAR PHOTOGRAPHY.

During the year ending August 31, 1920, the following solar photographs were taken with the 60-foot tower telescope by Messrs. Ellerman, Nicholson, Brackett, Hoge jr., Benioff, and Henshaw.

Photoheliograms of 6.5-inch image, 310 on 301 days.
Spectroheliograms with 5-foot spectroheliograph (*Hα*, entire 6.5-inch disk), 191 on 301 days.
Spectroheliograms with 13-foot spectroheliograph (K and *Hα*, 2-inch disk and prominences; portions of 6.5-inch disk with *Hα* and with monochromatic light from continuous spectrum), 990.

Photographic observations with the Snow and 150-foot tower telescopes are included in the following statements.

SUN-SPOT ACTIVITY.

The sun-spot activity continued to decline during the calendar year 1919, 295 groups having been observed as against 394 during 1918. There were no spotless days during the year, although there were 8 days on which only one group was recorded. June was the most active month, with 8 days on which more than 10 individual groups were observed. The greatest number seen on any one day was 13. August included the only other day in the year on which more than 10 groups were seen. The accompanying table gives the average number of groups observed per day each month:

Month.	Daily number.	Month.	Daily number.
January	4.1	July	6.0
February	4.7	August	6.1
March	4.9	September	5.1
April	4.0	October	4.1
May	5.7	November	3.3
June	8.5	December	4.0

The average latitude of all groups observed during the year was 12°, 1° less than the average for 1919.

SUN-SPOT POLARITIES.

Drawings of the solar image at the focal plane of the 150-foot tower telescope have been made daily, giving the approximate positions, polarities, and field-strengths of all spots large enough to be studied magnetically with the 75-foot spectrograph. There were few spots of "irregular" polarity, *i. e.*, that differed from the rule given in Mount Wilson Contribution No. 165 on "The Magnetic Polarity of Sun-Spots."

The following table, prepared by Mr. Nicholson, indicates the polarities of sun-spots observed in the northern and southern hemispheres during the calendar year 1919:[1]

Hemisphere.	Polarity.		
	Regular.	Irregular.	Undetermined.
North............	120	2	11
South............	152	3	7
Whole sun........	272	5	18

SUN-SPOT HYPOTHESES.

The various phenomena of the solar atmosphere, exhibiting some analogies and many sharp contrasts when compared with their nearest terrestrial equivalents, offer problems of extreme complexity. In attempting to deal with these problems, it is much easier to subject old hypotheses to destructive criticism than to substitute new ones that satisfy all the requirements. In his investigations of the nature of sun-spots, the Director has therefore made no effort to develop a general theory, or even to establish a particular hypothesis accounting for a part of the observed phenomena. The less ambitious plan has been adopted of selecting for comparative study three working hypotheses, two of which have been devised in the course of this investigation.

Each of these hypotheses assumes, in harmony with the indications of observation, that two vortices are involved in the system of a single spot, the first representing the spot proper and giving rise to its magnetic field, the second lying above it, accounting for the pattern of the hydrogen flocculi shown by the spectroheliograph. As 60 per cent of all spots are bipolar groups, while the great majority of other spots show tendencies toward the double type, a complete hypothesis must also explain this remarkable characteristic, and at the same time account for the complex groups of mixed polarities which sometimes appear on the sun. This demand, coupled with the ultimate necessity of explaining the regular variation of spots in latitude during the eleven-year cycle, the law of magnetic polarities, and, to mention no other general features, the sun-spot period itself, sets a sufficiently difficult task to the student of solar physics. When we reflect on the slow progress of terrestrial meteorology, however, we may rest content for the present with an unprejudiced examination of working hypotheses that may account for even a small percentage of the intricate phenomena presented by sun-spots.

[1] In the last annual report, on p. 229, the total number of spot-groups observed during the year should have been given as 394 instead of 314. The number of regular polarities in the table on p. 230 should have been given as 171, 187, and 358, instead of 131, 147, and 278 respectively.

Confining our attention, therefore, to single spots, and assuming, as already stated, that two superimposed vortices are involved in each, we may provisionally represent their structure in three different ways:

First, as presented by Evershed and St. John, who assume that the spot-vortex extends well into the photosphere, the circulation being spirally upward below the surface and then radially outward from the center of the spot above the penumbra through the lower reversing layer. A secondary vortex, with inward flow at high levels, is set up in the chromosphere by suction resulting from reduced pressure over the spot-vortex. The inward and outward flow of the spot-vapors, observed spectroscopically above and below the level of velocity inversion, do not represent the phenomena corresponding to the upper and lower extremities of a dumb-bell vortex, but do indicate the existence of two superposed vortices, in which the directions of whirl are not necessarily the same. The arguments supporting this hypothesis are fully set forth by St. John in Mount Wilson Contributions Nos. 69 and 74.

In the second hypothesis, the spot-vortex, of the dumb-bell type, lies for the most part above the photosphere. The inflow along its lower face is made visible by the penumbral filaments in the spot, while the outward flow near its upper face is shown by the Evershed effect in the lower reversing layer. The secondary vortex induced in the overlying chromosphere is of the same type as in the first hypothesis.

In the third hypothesis the spot-vortex lies chiefly below the photosphere, and its suctional effect at the surface is rendered visible by the structure of the penumbral filaments. The secondary vortex induced in the overlying chromosphere is of the dumb-bell type, the inflow in the upper chromosphere sweeping spirally downward and then nearly radially outward through the reversing layer.

In dealing with all of these hypotheses, both the hydrodynamic and the electrodynamic influence of the spot-vortex on the charged particles in the overlying solar atmosphere must be given adequate consideration, and the phenomena of bipolar spots must not be overlooked.

MOUNT WILSON MAP OF THE SUN-SPOT SPECTRUM.

In discriminating between rival sun-spot hypotheses, some of the most important criteria are to be found in the phenomena of the magnetic field. It thus becomes necessary to give special attention to the peculiarities of the Zeeman effect as exhibited by thousands of lines in the sun-spot spectrum. To facilitate a general study of these peculiarities, a photographic map of the sun-spot spectrum, on a scale of 1 cm. to the angstrom, has been prepared by Mr. Ellerman from enlargements of negatives made in the second order of the 75-foot spectrograph of the 150-foot tower telescope. This covers the region $\lambda3900$–$\lambda6600$, and is on a sufficiently large scale to bring out the details of many trip

lets and quadruplets rendered visible with the aid of a Nicol prism and compound quarter-wave plate. Copies of the map, in 54 sections of 50 angstroms each, will be placed on sale at cost.

In the examination of sun-spot hypotheses the most important evidence based on the Zeeman effect is probably that which indicates the decrease in field-strength observed at increasing elevations. This is plainly shown on the map, which also reveals other phenomena that will probably prove significant. Most of the triplets show maximum field-strength near the center of the spot, but others, representing higher levels, indicate no increase from the penumbra across the umbra.

A peculiarity of the central (p) component of spot triplets, mentioned in the last annual report, has been the subject of preliminary studies by Mr. Brackett and the Director, though the continuation of the investigation has been postponed pending the completion of a new solenoid magnet, inclosing a special electric furnace designed for the observation of the inverse Zeeman effect at various angles with the lines of force. A negative lens was mounted near the focus of the 150-foot tower telescope for the purpose of magnifying the image of a spot 1.4 diameters. With this degree of enlargement, a compound quarter-wave plate of 1-mm. strips, used with Nicol prism over the slit of the 75-foot spectrograph, permitted a large number of displacements of the p-component to be measured at regular intervals across typical spots. The results, in harmony with those mentioned last year, show that the p-component behaves as though it were composed of two members, circularly or elliptically polarized in opposite directions, and more widely separated near the outer edge of the penumbra, where the n-components indicate a weaker field, than in the strong field near the center of the spot. This remarkable behavior of the p-component, called for neither by theory nor by laboratory experience, deserves special attention in future investigations of the Zeeman effect.

PERIOD OF REVOLUTION OF THE SUN'S MAGNETIC AXIS.

In the last annual report there was reference to a short series of observations of the sun's general magnetic field made in September 1916. Measures of the plates taken on 7 days indicated that the period of revolution of the magnetic axis about the sun's axis of rotation, as given by the 1914 plates, was near the true value. During the past year Mr. van Maanen has measured 479 plates of the 1916 series, completing 22 days between September 2 and September 28. The final reduction of these measures has not yet been completed, but the present results show that the period of 31.52 ± 0.28 days given in the last annual report is very near to the truth. The difference for the 26 periods between the 1914 series and that of 1916 is not quite 3 days, or less than 0.12 day per period, which is well within the limits given by the probable error.

The recent marked decrease in the number of spots has permitted Mr. Ellerman to make a long series of photographs of spectra for the purposes of another determination of the magnetic elements of the sun.

SOLAR ROTATION.

A series of observations of the solar rotation, made with the 75-foot spectrograph of the 150-foot tower telescope under uniform conditions, was begun at Mount Wilson in 1914. Taken year by year, the period of rotation has proved to be practically constant. The sun is now approaching the period of minimum spot-activity, when changes in rotation associated with the sun-spot cycle should become manifest, if such exist. The next few years ought to furnish definitive data.

An improvement in the centering of the light-cone upon the grating is obtained by placing a 2-cm. diaphragm on the center of the telescope objective. The beam incident upon the grating is easily made rigorously central by adjusting the prisms for each exposure until the image of this spot is central upon the grating. An investigation is being made of the effects produced by more or less faulty centering, still keeping the illumination of the grating surface practically uniform when judged by the eye.

The completion of the Snow telescope equipment furnishes an opportunity for obtaining simultaneous observations with it and the 150-foot tower telescope, with which the long series is taken. It is hoped by this means to discriminate between effects due to solar causes and those due to instrumental and observing conditions.

GENERALIZED RELATIVITY.

The results of the British observations at the solar eclipse of 1919 have greatly increased the interest in the theory of generalized relativity. Of the three instances in which the deductions from Einstein's modified law of gravitation indicate effects within the range of observation, viz, the anomaly of Mercury's perihelion, the deviation of light in passing through the sun's gravitational field, and the gravitational displacement of the solar lines toward longer wave-lengths, the last presents the main outstanding discrepancy between theory and observation. In the opinion of Professor Einstein and the supporters of the theory of generalized relativity, a displacement of all solar lines to the red is a necessary and fundamental condition for its acceptance. A definitive result would be of great importance and is greatly to be desired from all points of view. In the annual report for 1917 the results of an investigation by Mr. St. John of the behavior of lines in the cyanogen band at λ3883 were given. These were unfavorable to the Einstein hypothesis. To this negative evidence may now be added that shown by the magnesium triplet in the green:

Center sun	5,167.336 A.	5,172.699 A.	5,183.619 A.
Reversed arc	5,167.336	5,172.696	5,183.618
Sun − arc	0.000	+0.003	+0.001
Limb − center	+0.002	+0.001	+0.001

The displacement deduced from the relativity hypothesis is 0.011 A.

Owing to the importance of the question in the theory of generalized relativity, as well as in the interpretation of solar and stellar spectrographic observations, a further and more comprehensive investigation is in progress. The behavior of the lines in the cyanogen band is being studied under decreasing pressure and the characteristics of their reversals in furnace spectra are under investigation. The complete achromatism of the image given by the Snow telescope furnishes exceptional conditions for studying the relative behavior of these lines at the center and limb of the sun.

An extensive investigation has been begun of lines whose behavior in the solar spectrum is exceptional, depending upon level, intensity, wave-length, or molecular weight. An accumulation of such data offers a promising means of reaching a more definitive conclusion upon the general question of displacement of solar lines as well as to the presence or absence of the Einstein displacement. The bearing upon these questions of the indirect study of the solar spectrum by means of observations of sunlight reflected from Venus is referred to in the report of that investigation.

RELATIVE WAVE-LENGTHS OF SKYLIGHT AND SUNLIGHT REFLECTED FROM VENUS.

Evershed finds that wave-lengths in the spectrum of Venus are always shorter than in the spectrum of direct sunlight. His observations show that the difference is very small when Venus and the earth are on the same side of the sun, but that the wave-lengths for Venus appear to decrease as the angle Venus-sun-earth increases. This observation is directly opposed to an explantion of the solar shift by the Einstein theory, anomalous dispersion, pressure effects, or convection currents in the reversing layer.

Spectrograms were secured at Mount Wilson by Messrs. St. John and Nicholson when Venus was east of the sun in 1919 and when west of the sun in 1919–20. Thirty lines in the region of $\lambda 4500$ have been compared with the same lines in the spectrum of the sky. The observations show a slight shift to the violet for the spectrum of Venus, -0.0026 ± 0.0004 A for the first series and -0.0006 ± 0.0008 A for the second. The mean difference, Venus *minus* sky, is -0.0017 ± 0.0004 A. This difference is near the limit of measurement, as indicated by the discrepancy between the two series for Venus and by the fact that mean wave-length of 30 lines on 23 sky-plates of the second series is 0.0008 A shorter than on 18 plates of the first series.

Tests of superimposed spectra showed that skylight with 5 per cent the intensity of Venus was sufficient to produce a shift of the order observed. When the angle Venus-sun-earth is large and Venus apparently close to the sun the plates must be taken at a very low altitude. On 18 nights, when Venus was near greatest elongation, both high

and low altitude plates were secured with an average difference in altitude of 13°4. Of these, 10 showed shorter wave-lengths for the lower altitude, 3 gave no difference, and 5 gave longer wave-lengths. The mean difference in wave-length was 0.0014 ± 0.0008 A. Since there was no change in the angle Venus-sun-earth between these plates there must be an effect, in some way due to the low altitude of the planet, which shortens the observed wave-lengths for Venus.

As the angle Venus-sun-earth changed, Venus was observed at different altitudes, so that the variation in wave-length which was found may be correlated with changes in either of these angles, but the low-altitude effect mentioned above indicates that the altitude of the planet is the vital factor in the observations.

SOLAR WAVE-LENGTHS.

It has long been recognized that the wave-lengths of Rowland's Preliminary Table of Solar Spectrum Wave-Lengths, owing to an error in his primary standard, do not represent absolute values in the C. G. S. system and that the errors in the relative wave-lengths due to the method of coincidence used in passing from his primary standard are roughly periodic. It was the opinion of the solar physicists at the Brussels meeting of the International Astronomical Union in 1919 that the time had arrived when consideration should be given to the preparation of a table of solar wave-lengths based upon the international system. It was with that end in view that the chairmanship of the International Commission of Standards of Wave-Lengths was assigned to Mr. St. John, of the Mount Wilson Observatory.

The first step is the determination of the wave-lengths of a series of solar standards in the international system. For some time this work has been under way at Mount Wilson through comparison of simultaneous spectrograms of the sun and the iron arc. Some preliminary work on the application of the interferometer to solar observations was carried on by Mr. Babcock last summer. The results showed that the designs of the instrumental equipment were suitable to the purpose and that the accuracy obtainable was of the same order as in the grating method.

A program whose immediate purpose is the precision measurement of the wave-lengths of a series of solar standards and of lines whose behavior in the solar atmosphere is important in other observations is in progress. The comparison of the double series, by grating and interferometer, will furnish, it is hoped, a criterion of the reliability of the Mount Wilson determination. The program includes, further, an investigation of the degree of stability of the wave-lengths of the solar lines at the sun's center and other related regions, also a comparative study of the wave-lengths, at the elevations of Pasadena (800 feet) and of Mount Wilson (5,650 feet), of the atmospheric lines due re-

spectively to oxygen and water-vapor. Their increasing importance as reference lines requires more definite knowledge of their behavior under varying conditions (pp. 259, 260).

INFRA-RED SOLAR SPECTRUM.

The infra-red solar spectrum has been photographed by Mr. Brackett to λ9900 on Seed 23 plates bathed with dicyanin. Preliminary analysis, by means of a Hilger monochrometer, was effective in removing the scattered light which had obliterated the finer structure on previous photographs.

The region between λ9000 and λ9350 proves to be particularly rich in fine lines. On the other hand, the region between λ9300 and λ9500 is characterized by broad diffuse radiations covering several angstroms, unresolved with a dispersion of 3 angstroms to the millimeter. Beyond this point the finer structure agains appears until it is lost because of the rapidly falling sensitiveness of the plate.

Solar-rotation plates have been obtained as far as λ9750, which serve to distinguish the solar from the telluric lines.

Preliminary determinations of wave-lengths have been made throughout the whole region. More than 550 lines in all have been measured, of which roughly 10 per cent prove to be solar. The larger portion is probably due to water-vapor, as shown by the remarkable increase in intensity during times of high humidity.

RESEARCHES ON STARS AND NEBULÆ.

OBSERVING CONDITIONS.

The conditions for night observing for the year ending August 31, 1920, are shown in detail by the subjoined tables, compiled from records of the 60-inch reflector. The conditions were slightly better than the mean for the past eight years. The 60-inch telescope was in use 65 per cent of the hours of darkness. The total exposure-time was 71 per cent of the available observing weather and 46 per cent of the total hours of darkness. Weather conditions recorded by the Government instruments at the Observatory show for the year a mean temperature of 54° F.; a maximum of 95° F. on August 13, and a minimum of 15° F. on November 28. The total precipitation was 31.19 inches, being a little below normal; the total snowfall, 43 inches. The average wind velocity was 10.7 miles per hour.

The most destructive forest fire ever known in the vicinity broke out on September 12, 1919. Two serious fires were in progress at the same time, one about 20 miles to the northeast and one about the same distance northwest of the Observatory. The smoke became so dense at Mount Wilson that observations were entirely prevented on several nights. These fires were beyond control for two weeks, and at times threatened to reach the observatory grounds. Fortunately, a heavy rainstorm on September 26 extinguished the fires completely.

Seeing.		Wind.	
Scale.	No. of nights.	Velocity.	No. of nights.
1	42	High.........	16
2	40	Brisk........	29
3	55	Moderate.....	41
4	51	High.........	134
5	57	Calm.	105
6	28	....	....
7	9	....	....
8	1	....	....

Observing Record of 60-Inch Reflector.

Month.	Hours of darkness.	Hours clear.	Hours cloudy.	Hours for silvering and repairs.	Hours exposure time.	Observations.		
						All night.	Part of night.	None.
1919.								
September.......	295	202	93	....	138	19	4	7
October.........	336	261	75	....	189	22	6	3
November.......	330	232	98	....	184	17	8	5
December........	346	181	165	....	122	11	12	8
1920.								
January.........	346	134	212	45	68	5	7	19
February........	318	128	190	....	78	8	9	12
March...........	324	176	148	2	126	15	5	11
April............	286	170	116	18	128	15	7	8
May............	266	186	80	....	135	17	8	6
June............	230	212	18	....	165	25	4	1
July.............	255	220	35	....	163	24	7	0
August..........	269	261	8	1	181	27	3	1
Totals........	3,601	2,363	1,238	66	1,677	205	80	81
Mean for 8 years.......	....	2,306	1,280	....	1,631	193	90	82

COMPARATIVE TESTS OF THE 100-INCH AND 60-INCH REFLECTORS.

Last year's report gives a detailed account of comparative tests of the large reflectors when used for the photography of stellar spectra. Further experience confirms these results, which show that the threefold light-gathering power of the 100-inch reflector over that of the 60-inch is very nearly utilized to its full extent. A plane mirror used in the optical train of the spectrograph on the 60-inch reflector is eliminated from that of the 100-inch, which secures a small gain of light for the latter. With allowance for this fact, it is found that the relative exposure-times average about 1 to 2.5 for the same stars. This mean result refers to the same slit-width and the same length of camera, but includes a wide range in the seeing and in the figure of the mirrors.

To test the two instruments for limiting magnitude and resolution, several series of photographs have been made under identical conditions

by Mr. Seares, assisted by Messrs. Hubble and Duncan. Equal exposures were made simultaneously with the two telescopes to the same field, using plates from the same box, which were afterwards developed in the same tray. To eliminate the influence of accidental variations in the sensitiveness of the plates, two or more photographs of the same field were made in each series.

The results for limiting magnitude are shown in the accompanying tables. All the photographs were on Seed 30 plates, exposed to Selected Area 87, for which the photographic magnitudes on the normal scale, referred to the international zero-point, are well determined. The

Limiting magnitudes, 100-inch and 60-inch reflectors.

Date.	Exp.	100-inch.				60-inch.				Gain.
		Pl.	Images.	Seeing.	Limit.	Pl.	Images.	Seeing.	Limit.	
1920.	m.									
May 22...	5	4	Large, Sl. El.	5	18.36	5292	Excellent.	6	17.82	+0.54
	3	5	Large, El....	5	17.84	5293	Sl. El....	6	17.42	+0.42
	3	6	Large, Sl. E..	5	17.83	5294	Good....	6	17.61	+0.22
Aug. 14...	2	5505	Good.......	4	17.67	1	Sl. El....	4	16.88	+0.79
	2	5506	Good.......	4	17.64	2	Good....	4	16.82	+0.82
	2	5507	Good.......	4	17.65	3	Good....	4	16.85	+0.80
Aug. 15...	2	H 68	Good.......	6	17.75	5532	Poor, El..	6	16.67	+1.08
	2	H 69	Good.......	6	17.80	5533	Sl. El....	6	16.88	+0.92

May 22: Not representative of the performance of the 100-inch. Images very large as compared with those of August 14 and 15. Mirror astigmatic; figure of 60-inch excellent.

August 14: A fair test of both instruments. Note consistency of limits.

August 15: Gain for first pair too large because of poor images on 60-inch plate. The second pair is a fair comparison.

limit was obtained by selecting 10 or 12 stars on each plate, just faintly visible, and estimating in tenths of a magnitude the interval separating their images from the limit. The known magnitude, plus the estimated interval, thus gives for each star a value of the limit. The tabular values are the mean results for individual plates. The probable error arising from the estimates is 0.03 or 0.04 magnitude.

For a 2^m exposure on Seed 30 plates we may accept as representative:

Seeing.	100-inch.	60-inch.	Gain.
4	17.6^5	16.8^5	0.8 mag.
6	17.8	16.9	0.9

A similar plan was followed in the tests of resolution, the fields in this case being the central part of the extended nebulosity M 8, and the planetary nebula N. G. C. 7009, which is especially rich in fine, delicate detail. One pair of plates of the Ring Nebula in Lyra was also made, but the 100-inch photograph is defective through faulty guiding.

Of M 8, 7 pairs of plates were made with exposures of from 3^m to 15^m, the seeing ranging from 3 to 5 on a scale of 10. N. G. C. 7009 was photographed on a single pair of Seed 23 plates with exposures of 20^s, 1^m, 3^m, and 9^m. For examination, corresponding pairs of negatives were mounted together on one of the measuring-machines which had been supplied with an additional microscope, so that the observer might look quickly from one plate to the other in comparing the details photographed with the two instruments. The magnification was adjusted to bring the image of the 60-inch plate to the same scale as that of the 100-inch.

Extended masses of nebulosity show the same density, as was to be expected, since the two instruments are of the same focal-ratio. But in resolution, a glance is sufficient to show the superiority of the 100-inch over the 60-inch, even in the case of M8, photographed at a zenith distance of 60° with seeing as low as 3.

The results for the Hooker telescope in the case of N. G. C. 7009, photographed at zenith distance 46°, seeing 6, are very much the superior of the two. Fine details are clearly shown which can not be traced on the 60-inch negative, or at most are only suggested by irregular and undefined masses of silver grains. It is noteworthy, too, that small details approximating star-images in size, such as the ansæ, are stronger on the 100-inch negative than on the 60-inch, although the relatively large central part of the nebula is strictly comparable in density on the two negatives.

Greater resolution is of course to be expected from the larger instrument, because of the increase of scale in the ratio of 10 to 6, provided the linear increase in the excursions of the optical image do not nullify the advantage thus derived. These tests show conclusively that there is a decided gain in resolution with seeing as low as 3 on a scale of 10.

PHOTOGRAPHS OF NEBULÆ AND CLUSTERS.

The following photographs of nebulæ and clusters were made by Mr. Pease with the 60-inch telescope for classification and study:

N. G. C. 2146.	Abnormal spiral.
N. G. C. 3310.	Spiral.
N. G. C. 5595, 5597.	Spirals.
N. G. C. 6053.	A group of small nebulæ and nebulous stars.
N. G. C. 6401.	Star-clusters.
N. G. C. 6595.	Two stars involved in nebulosity.
N. G. C. 6643.	Spiral.
N. G. C. 6906.	Spiral.
N. G. C. 6969.	Winged nucleus.
N. G. C. 7722.	Spiral with absorption streak.

With the 100-inch telescope Mr. Pease made direct photographs of N. G. C. 598, 2022, 2274, 3379, 3395–6, 4656–7, 7026, 7662, the Orion Nebula, and Nova Aquilæ. All of these nebulæ are well-known objects and have been previously described.

Additional photographs made by Mr. Pease with this telescope for classification include N. G. C. 5655 and a small spiral, and the region surrounding N. G. C. 4009, which proves to be a group of 45 or more

small nebulæ and nebulous stars. This group is worthy of attention, as it contains several spindles, several spirals in plan, and an interesting double spiral.

Mr. Duncan made long-exposure photographs of N. G. C. 6960 and M 16 and 33 with the 60-inch telescope and of the Andromeda Nebula and M 8 with the 100-inch. He also photographed the Dumb-bell Nebula with the latter instrument.

Mr. Hubble has photographed the following nebulæ and nebulous stars with the large reflectors, using the Newtonian focus:

60-inch reflector.

B. D.	+64°13	B. D.	+34°980	N. G. C.	3458	I. C. 4603
I. C.	48	I. C.	423	N. G. C.	3550	I. C. 4605
N. G. C.	274–5	Jonck.	900	N. G. C.	3596	I. C. 1295
N. G. C.	281	N. G. C.	2245	N. G. C.	4278	I. C. 4954–5
B. D.	+29°565	I. C.	446	N. G. C.	4472	
N. G. C.	1333	N. G. C.	2261 (9 pls.)	N. G. C.	4621	I. C. 6914
I. C.	1985	B. D.	−12°1771	N. G. C.	4846	I. C. 7309
N. G. C.	1555	N. G. C.	2608	B. D.	−19°4357	I. C. 7513
N. G. C.	1788	N. G. C.	2701	B. D.	−19°4359	
				B. D.	−19°4361	

100-inch reflector.

B. D.	+31°597	N. G. C.	2261 (7 pls.)	N. G. C.	6072	B. D.	−32°14673
B. D.	+30°540	N. G. C.	2578	B. D.	−19°4357	M	57
N. G. C.	1514	T Pixidis		ρ Ophiuchi		N. G. C.	6729 (25 pls.)
N. G. C.	1555	N. G. C.	4278	N. G. C.	6357	N. G. C.	6821
N. G. C.	1976	N. G. C.	4486	M	8	N. G. C.	7009
B. D.	− 2°1345	N. G. C.	4649	B. D.	−23°13908	I. C.	1392
Uncatalogued object.		N. G. C.	5128	I. C.	1274–5	N. G. C.	7293
$\alpha = 6^h\ 3^m$, $\delta = +18°\ 42'$		N. G. C.	5367	N. G. C.	6589–90	N. G. C.	7625
N. G. C.	2247	N. G. C.	5968	I. C.	1287		

In the course of this work Mr. Hubble has added three planetary nebulæ and two globular clusters to the lists of known objects.

Faint Novæ have been found in the Andromeda Nebula as follows: No. 14 by Miss Ritchie, No. 15 by Mr. Duncan, No. 16 by Mr. Shapley, and No. 17 by Mr. Humason. No. 16 was observed visually with the 100-inch reflector, probably the first visual record of a Nova in the Andromeda Nebula since that of the seventh-magnitude star, No. 1, which appeared in 1885. No. 17 was nearer the center and brighter than any Nova since No. 1.

A number of color-photographs of nebulæ have been made by Mr. Seares during the year, but no discussion of the data has thus far been possible. Panchromatic plates exposed behind a red filter transmitting to the red of λ5700 confirm the earlier results on spirals obtained with isochromatic plates and a yellow filter. A four-hour exposure on M 51, for example, gives strong red images for the central and secondary nuclei, but shows no trace of the arms of the spiral. A yellow exposure on the Dumb-bell Nebula gives a result strikingly different from the usual violet-blue photograph. The yellow light is less widely distributed and presents the appearance of diffuse nebulosity, with no trace of the rich detail revealed by an ordinary plate.

Mr. Humason has taken the following photographs of star-fields with the 10-inch telescope: 46 exposures of 60 minutes each for photometric purposes on four areas in the Milky Way, each covering an area of 340 square degrees, from $\delta = +24°$ to $-40°$; three photographs of each of three special fields (a faint variable star, of which 18 small plates were taken, was found on one of these; it appears to be an eclipsing binary); five photographs of Præsepe and 5 of M 22; 6 exposures in and near Orion and 3 of the double cluster in Perseus.

VARIABLE NEBULÆ.

Among these objects are the three known variable nebulæ N. G. C. 1555, 2261, and 6729, all of which are under observation. A series of plates of N. G. C. 2261 was made by Mr. Hubble on 10 nights with the large reflectors, and N. G. C. 6729 has been photographed on 12 nights to date. The variation is rapid and extensive in both nebulæ. The observations are not yet complete enough for thorough discussion, but thus far they suggest a permanent framework of nebulous detail on which occur both local brightening and local obscuration. The obscured region on N. G. C. 2261 brightened up during the season in a progressive manner, obliquely across the nebula and toward the nucleus. No evidence has been found of actual motion of luminous detail. N. G. C. 6729 shows decided changes in an interval of 24 hours. N. G. C. 1555, of which only one plate has been taken this year, shows considerable exterior nebulosity as far as 3′ from T Tauri, which has not previously been photographed.

DIFFUSE NEBULÆ AND NEBULOUS STARS.

Some 40 nebulous stars and diffuse nebulæ have been photographed by Mr. Hubble with the large reflectors for study of structural detail and for comparison with future plates for changes. Two features are emphasized in these objects—the frequency in the smaller dense nebulæ of double stellar nuclei and the streaming of nebulosity around and past involved stars, indicated by dark lanes leading away from the stars. Direct photographs have been made by Mr. Hubble with the 10-inch telescope for the following purposes: (1) identification and classification of little-known nebulæ (a weeding-out process of the reflector program); (2) the distribution of nebulæ on the general background of the sky; (3) structure of very large nebulæ and nebulous regions; (4) structure of dark markings.

Experiments with prolonged exposures suggest that under the average conditions on Mount Wilson the maximum efficient exposure-time for a moonless sky, with a Seed 30 plate and a focal ratio of 4.5, is of the order of 12 hours. Longer exposures seem to lose more by sky-fog than they gain by building up the images of nebulæ and stars.

Small-scale photographs of the Milky Way regions were obtained by clamping to the tube of the 10-inch telescope a 4 by 5 box-camera

carrying a Tessar Ic lens of 6.5 inches focus, focal ratio 4.5, loaned by Mr. Edison Hoge. This lens gives extremely good definition over a field more than 30° in diameter. The plates show the large features of the Milky Way on a field and scale convenient for studying the relation of star-clouds, absorbing regions, and dark markings. Several large dark areas, not previously known, have been found at upwards of 20° from the galactic plane. The photographs suggest that these dark regions lie on a plane inclined to the Galaxy some 12°, which seems to coincide with the plane of the local cluster of B stars. This furnishes further evidence of the close relationship of B stars and diffuse nebulosity. The plates further suggest that the abrupt ending of the northern branch of the Milky Way in Ophiuchus may be due to a general absorption in that region.

SPECTRA OF NEBULÆ AND NEBULOUS STARS.

Two objective prisms, one of 6° angle, the other of 15°, have been used by Mr. Hubble with the 10-inch telescope for the following purposes: (1) special types of nebulous stars; (2) differentiation of nebular spectra (whether bright line or continuous); (3) study of stellar spectra in dark regions.

Nebulæ which have not previously been classified have spectra as follows:

Bright-line spectra.		Continuous spectra.
N. G. C. 281	N. G. C. 2359	N. G. C. 1333
I. C. 2003	N. G. C. 5128	N. G. C. 1579
N. G. C. 1465	N. G. C. 6072	N. G. C. 1788
N. G. C. 1499	N. G. C. 6357	I. C. 360
N. G. C. 2237	N. G. C. 7635	I. C. 446
C. D. −32°14673		

The variable nebula N. G. C. 6729, for which Slipher announced a spectrum similar to Nova Aurigæ, was found to possess a strong, bright $H\alpha$ line.

Attempts were also made by Mr. Hubble to determine the general characteristics of objective-prism spectra of extra-galactic nebulæ (spirals, etc., in high galactic latitudes). An exposure of 5 hours with the 6° prism gives traces of practically all N. G. C. objects; 215 such nebular spectra have been obtained. Lines are rarely seen, but the distribution of light suggests the predominance of solar types, in agreement with previous results. Five of the 215 spectra show traces of bright lines; of these, 3 are previously known cases of bright-line spirals.

Work with the 10-inch telescope has been supplemented with another type of instrument—large-angle prisms mounted in front of a fast

short-focus lens of ratio F 1.8. The resulting small image and large dispersion give promising preliminary results in the study of such faint extensive objects as the exterior nebulosity in Orion.

A provisional classification of the spectra of 90 nebulous stars clearly indicates a progression in type with decreasing brightness. Almost without exception the objects brighter than magnitude 7.5 are of a type earlier than B 5. Fainter stars are distributed uniformly over the range B0 to A 3. Two stars, B. D. +31°597, 7.5, and −19°4357, 6.2, are, however, of advanced type, being G 5 and K 0, respectively.

The spectrographs at the Cassegrain focus of the 60-inch and 100-inch telescopes have been used by Mr. Hubble for a detailed study of the spectra of some 25 nebulous stars. No characteristic deviation from a normal distribution of lines has been detected. Two of these stars have the enhanced lines of α Cygni and two are of late type—G 5 and K0. In these four cases some idea of the absolute magnitude, and hence of the parallax, can be obtained by the spectroscopic method. One star shows bright $H\alpha$ and $H\beta$, the latter, at least, reversed in the center. Radial velocities are being determined and the plates on hand suggest a high percentage of binaries.

COLOR OF NEBULOUS STARS.

The importance of the continuous part of these spectra is emphasized by the abnormally large color-index which nebulous stars are now known to possess. It had been noticed by Mr. Hubble that certain nebulous stars looked decidedly yellowish in the telescope, and when their spectra were found to be of early type, the matter was investigated photographically by Mr. Seares and Mr. Hubble, using the method of exposure ratios with the 60-inch reflector. For certain of the stars, color-indices were also determined by polar comparisons with the 10-inch telescope. Complete data—spectra as well as colors—are now available for 42 objects, and it is found that as a class these stars are appreciably redder than would be inferred from their spectral type. The amount of the color excess varies between rather wide limits, but in the average corresponds to about one spectral subdivision or 0.4 mag. in the color index. B. D. −12°1771 is the only conspicuous exception, although a few stars, formerly supposed to be nebulous, show little or no color excess. Long-exposure photographs indicate, however, that none of these objects is nebulous in the sense defined by Herschel. At the other extreme is B. D. −22°4510, the central star in the northern mass of the Trifid Nebula. Its spectrum is A 3, while the color class is *g* 4. The color excess is thus 2.1 spectral subdivisions, or about 0.8 mag. B. D. −6°1415 (N. G. C. 2170) shows an even larger excess of color, but the result is uncertain and requires confirmation. A plausible explanation of the phenomenon is that the light of these stars is scattered by the surrounding nebulosity, but the possibility of some form of resonance excitation should also be borne in mind.

PARALLAX OF NEBULÆ.

Four methods have thus far been employed by Mr. Hubble for determining the distances of nebulous stars and diffuse nebulosity:

(1) Spectroscopic method for certain stars. This has been applied to 4 out of the 25 available spectra.

(2) From apparent magnitudes, on assumption of small dispersion in absolute magnitudes; 40 magnitudes have been obtained so far by polar comparisons with the 10-inch telescope.

(3) Proper motion. The available published data have been compiled, and a program is being prepared to determine the proper motions of the remaining stars.

(4) Apparent magnitudes of stars superposed on, and blotted out by, diffuse nebulosity, both luminous and dark. A half-dozen plates have been secured for this purpose, but no measures have been made as yet.

TRIGONOMETRIC STELLAR PARALLAXES AND PROPER MOTIONS.

During the year Mr. van Maanen made 534 photographs, including 817 exposures, at the 80-foot focus of the 60-inch reflector; 347 of these with 638 exposures were taken for parallax measures; 138 with 167 exposures were for proper motions; and 8 with 12 exposures for miscellaneous purposes.

For 22 fields the necessary plates were secured for the determination of parallaxes, thus giving a total of 122 fields finished to date. Among these were the central stars of 4 additional planetary nebulæ, N. G. C. 40, 2022, 6210, and 6543; one spiral nebula, N. G. C. 4051; and Campbell's hydrogen-envelope star, B. D. +30°3639. Including B. D. +30°3639 among the planetaries, the mean absolute magnitude of the central stars of the 11 objects for which the parallaxes have now been completed is +8.2, thus confirming the low absolute magnitude of the central stars of planetaries mentioned in the last report.

When the first 100 parallaxes were finished, an investigation was made of the systematic errors affecting these results. The following conclusions were derived by Mr. van Maanen from this study:

(1) A comparison of 16 fields observed in common with other observers indicates a systematic error of $-0\overset{''}{.}001$.

(2) A comparison of the proper motions in right ascension with those given by Boss indicates an error of $-0\overset{''}{.}001$.

(3) A comparison with Kapteyn's tables for mean parallaxes indicates for the Mount Wilson parallaxes an error of $+0\overset{''}{.}001$. This comparison also shows that the parallaxes are apparently free from systematic errors which are functions of either right ascension or proper motion.

(4) A comparison of the mean absolute magnitudes and the mean τ-component of the proper motions, expressed in kilometers per second, for different groups of stars, with accepted results for intrinsic brightness and stellar velocities, indicates an error of $+0\overset{''}{.}001$ or $+0\overset{''}{.}002$.

(5) A comparison with a system of mean parallaxes based on the directly measured parallaxes of all observers indicates an error of $+0\overset{''}{.}002$.

From the five different methods used, Mr. van Maanen finds that the systematic error of the Mount Wilson trigonometrical parallaxes does not appear to exceed $0\overset{''}{.}002$. For the last comparison it was thought worth while to derive the systematic deviations of other series of parallaxes as well. A discussion of all the available material led him to conclude that while in most of the modern series of parallaxes the systematic deviations are small, they can not be neglected when the highest accuracy is required. The method followed is, in brief, thus: All stars for which the parallax, proper motion, magnitude, and spectral type are known, 901 in all, with 1,583 observations of parallax, were made to fit an exponential formula of the type proposed by Kapteyn. The constants of the formula were determined for each spectral type separately, using two different systems of weighting. The deviation from the mean system thus established was then determined for each observer. The results show that for practically all series of observations the systematic deviation from the mean system is not a function of spectral type or of proper motion, but in most cases is dependent on the magnitude. The only exceptions are the Allegheny, Greenwich, Mount Wilson, McCormick, and Yerkes parallaxes. The application of these systematic deviations to the individual parallaxes of the stars measured by more than one observer reduces the differences in 65 per cent of the cases, while for 19 stars with six or more available observations their use improves the agreement in 72 per cent of the cases.

The search for faint stars of large proper motion was continued. Although 23 fields have been examined, for which the interval is 4 or 5 years, only two cases were found, both on parallax plates: near Boss 1182, a star of photographic magnitude 13.2 with an annual motion of $0\overset{''}{.}38$, and near W Ursæ Majoris a star of magnitude 14.1 with a motion of $0\overset{''}{.}92$. With this interval motions of half a second or more annually can be detected on photographs taken at the 80-foot focus by simply superposing the plates. As each plate of 15 minutes' exposure contains from 35 to 200 stars, it is clear that the number of faint stars with motions exceeding $0\overset{''}{.}50$ annually must be very small.

A series of photographs duplicating some of the old parallax-plates has been begun, from which it is hoped that it will be possible to derive the parallactic motion, and possibly the stream-motion, of the stars as faint as the twelfth magnitude.

LUNAR PHOTOGRAPHY.

Mr. Pease has photographed the moon at the 134-foot focus of the 100-inch telescope on 9 nights. The photographs of September 15, 1919, when combined stereoscopically with those of August 5, 1920, which are at practically the same phase (21.5 days), show strong relief, because of the displacement produced by libration. The small details

brought out by these photographs, and the structure rendered visible by the aid of the stereoscope, should make them of considerable value to selenologists.

A few planetary photographs have also been taken, but not under good atmospheric conditions.

STELLAR PHOTOMETRY.

The observational part of the investigations in stellar photometry by Mr. Seares and Mr. Shapley includes 632 photographs made with the 60-inch and the 100-inch Hooker reflectors, distributed as follows:

Selected areas	153
Clusters	100
Color photographs	126
Nebulæ	43
Galactic clouds	182
Miscellaneous	28
	632

Photographic Magnitudes for the Selected Areas.

The determination of the magnitudes for Areas Nos. 1 to 139, to the limit shown by an exposure of 15 minutes with the 60-inch reflector, has been finished by Mr. Seares with the assistance of Miss Joyner and Miss Richmond. The results are on the normal scale, and have been reduced to the international zero-point by methods which provide a series of closing conditions similar to those of a triangulation net.

The closing errors, in hundredths of a magnitude, are shown by the accompanying table. A "circuit" includes, in general, 6 fields, one of which is the standard region at the pole. For the zones, the number of fields is 6 at 75°, 12 at 60°, and 24 for each of the remaining zones. These outstanding deviations were made the basis for the final adjustment of the zero-points in each of the 139 areas. Rectangular coordinates of the stars in all the areas but three have been measured with sufficient precision for identification.

Circuit.	+75°	+60°	+45°	+30°	+15°	0°	−15°
1	0	+11	+24	− 5	+ 5	+ 9	0
2	+ 6	+19	+22	+19	+20	−13	+28
3	0	+ 7	−12	−31	+ 1	− 5	−22
4	0	−16	+ 1	−15	+ 4	+ 5	+ 3
5	−13	−14	−31	+ 5	− 7	− 1	+14
6	−11	+ 1	−15	− 2	0	− 1	−22
Zone	−18	+8	−11	−29	+23	−6	+1

The final catalogue will include these results, combined with measures on photographs with multiple exposures of 60 and 5 minutes which should extend the scale about a magnitude below that of the plates of 15 minutes' exposure. The long-exposure photographs have

been completely measured at Groningen under the direction of Professor Kapteyn and Dr. van Rhijn. Results for the Areas 1 to 25, including about 7,000 stars, are now in our hands, and their combination with our own measures is practically complete.

Photovisual Magnitudes for the Selected Areas.

The determination of the photovisual magnitudes by Mr. Seares and Mr. Shapley for 43 of the Selected Areas has progressed slowly, owing to concentration of effort on the program for the photographic magnitudes. The photographs, with the exception of a dozen plates, have all been obtained. The measures by Miss Joyner and Miss Richmond are well advanced, but little has thus far been done with the reductions.

Constitution of the Galactic Clouds.

In continuation of the study of the distribution of the stars, a series of photographs has been made by Mr. Seares with the 60-inch reflector of fields in and near some of the conspicuous galactic clouds, for the purpose of determining the brightness and number of stars of which they are composed.

To avoid the very great labor which would be involved in deriving magnitudes for the individual stars, the results will be based on counts of stars to the limits determined by a definite series of exposures. In general, six or eight fields are chosen for each of the clouds studied, at intervals of about a degree, so that the series extends across the cloud and connects with the regions of smaller star density on either side. Exposures of 20 seconds and 1, 3, 9, and 27 minutes are made in succession on each field, under good observing conditions. In addition, at least one series of control exposures is made during each night of observation on a neighboring Selected Area, for which the magnitudes are known. The latter series will serve to determine the limiting magnitudes corresponding to the various exposure-times. Care is taken to use only plates of the same emulsion on any given night. It is believed that this procedure will yield reliable results with a minimum of labor.

Brightness of the Galactic System.

The recent determination of the density and luminosity laws by Professor Kapteyn and Dr. van Rhijn has led Mr. Seares to compute the surface brightness of the galactic system as it would appear from a distant external point in the direction of the galactic pole. The equivalent apparent magnitude of an area of 1 square second of arc at the center of figure of the system seen in projection is approximately 23. The decrease in brightness from the center outward is slow, amounting to less than 2 magnitudes in a distance of 5,000 parsecs.

The results bear upon the question of the relation of the spiral nebulæ to the galactic system. The surface brightness of all nebulæ known is

greater than that of the Galaxy, and for a considerable number of the brighter spirals the factor is of the order of 100.

If we suppose the spirals to consist of aggregations of stars similar to our own system, we arrive at the following relation between the number of stars per unit volume, δ, and the linear dimensions, T,

$$\frac{\delta_S}{\delta_G} = I\frac{T_G}{T_S}.$$

The subscripts S and G refer to the spirals and the galactic system, respectively, and I is the ratio of the surface brightness of the nebulæ to that of the Galaxy. As remarked above, this quantity is always greater than unity, and in a considerable number of cases attains values of the order of 100. Alternative conclusions concerning the relative values of δ and T are obvious, and it appears that if we arrange the spirals and the galactic system according to one or the other of these characteristics, the Galaxy will be at one end, if not actually outside, the series thus formed. If, therefore, the spirals really consist of stars, they are not in general comparable with our own system in respect to both stellar density and linear dimensions.

Observations of Color.

The measurement of the color of stars of known intrinsic brightness by the method of exposure ratios has been continued by Mr. Seares. In addition to the blue-yellow ratio, a considerable number of measures has been made in the red in combination with other spectral regions in the hope of discovering criteria which would permit the determination of both spectrum and luminosity from observations of color alone. For the regions thus far used the problem seems to be indeterminate, owing to the fact that the effect of luminosity on color enters in such a manner that it can not be separated from that due to spectral type. If the spectrum is known, observations of color, at least in the case of the late A's and the G and K stars, can be made with sufficient precision to afford approximate values of the luminosity, and hence of the distance. But in that case there is no great gain, for the distance can then be obtained directly from the spectrum.

Intimately related to this question is the dependence upon luminosity of the effective temperatures calculated by Planck's radiation formula. We should expect a dwarf star to yield a higher black-body temperature than a giant of the same spectral type, and an examination of the measures of Wilsing, Scheiner, and Münch shows this to be the case. The behavior of the spectral lines used as criteria for the determination of absolute magnitude would indicate the contrary, however, which throws some light upon the deviations of black-body temperatures from the true temperatures of stars.

A further indication of the complexity of the energy relations in the spectrum is indicated by the fact that the curves found by plotting exposure ratios for different regions of the spectrum against each other, for example, violet-yellow against violet-red, seem to be smoother than those found by plotting either ratio against the spectral types of the stars in question. The deviations are larger than the uncertainties in the spectral classification, and suggest that there are other elements besides luminosity and spectral type which determine the color of a star. In fact, the correlation with luminosity is probably more or less artificial, atmospheric absorption doubtless being the fundamental factor.

The method of exposure ratios has also been used by Mr. Seares and Mr. Hubble to determine the colors of the nebulous stars of Herschel. An account of the results is given on page 236.

Investigations of Star-Clusters.

As stated in earlier reports, the distribution of stellar clusters in space has led Mr. Shapley to the conclusion that the galactic system is very much larger than was generally supposed before the inception of work on clusters at Mount Wilson. Some students of the subject have naturally hesitated to accept a pronounced modification of long-standing interpretations, and it is therefore important to develop new methods of determining the distance of clusters. To establish the new view of galactic dimensions, it is sufficient to show that the cluster stars are of high intrinsic luminosity, because the brightest stars in globular clusters must be giants if the size of the sidereal universe is of the order assigned by Mr. Shapley, while if the older view holds, these stars must be dwarfs.

An examination of the spectra of some of these stars of types G and K by Mr. Adams has already shown that they have the characteristics of giants. A comparison of the distribution of energy in the spectra with the corresponding spectral types of these objects by Mr. Shapley by an extension of the method used by Adams and Kohlschütter also shows that this conclusion must be accepted. A 6° prism, 14 inches in diameter, was placed in the converging beam about 20 inches from the secondary (134-foot) focus of the 100-inch telescope. Small stellar spectra (chromatically elongated images) may be photographed through the prism, over a field of about 10′ radius. When specially sensitized plates are used, the whole interval from λ3800 to λ7500 is recorded, with a break in the middle due to the relative insensitiveness of the plate to yellow-green light. The blue-violet half of one of these chromatic images represents that part of the starlight photographed on ordinary plates; the other half lies in the red and infra-red, a region that has been comparatively little studied in stellar spectra. The relative intensity of the two halves depends on spectral type, but for

red stars of the same type (with the possible exception of the M's) as Adams, Kohlschütter, Seares, and others have shown, the giants are much redder than the dwarfs. To test cluster-stars for luminosity, well-known giants and dwarfs of the solar neighborhood have been photographed on the same plate with the cluster. A direct comparison of the chromatic images of giants, dwarfs, and cluster-stars of the same spectral types indicates that the cluster-stars are giants. The work is being continued and an attempt will be made to place the method on a quantitative basis, though the difficulties pointed out by Mr. Seares in his discussion of the relation of color to intrinsic luminosity remain to be overcome.

The detailed photometric catalogue of 848 bright stars in M3 has been published by Mr. Shapley and Miss Davis. It affords valuable material for the discussion of the properties of stars in globular clusters, and serves to corroborate rather than to modify the principal results obtained from the earlier and similar photometric study of M 13. Omitting variables, the spectral curve of M 3 shows a maximum frequency near color-class $f\,5$; the magnitude curve shows a maximum frequency for photovisual magnitude 15.5 (near absolute magnitude zero) and, as usual, is far from being symmetrical. The relation of color-index to magnitude shows the customary decrease of index with decreasing brightness.

A more comprehensive discussion of stars of the highest luminosity has been based upon the analysis of 1,152 giant stars in 9 clusters, for which distances, colors, and apparent magnitudes have been obtained at Mount Wilson during the last five years. From this work it appears that very few stars in clusters are brighter photovisually than −4, and none has been found to exceed photovisual magnitude −6 absolute.

The problem of dwarf stars in clusters is one that merits attention because of its bearing on the relation of globular to open clusters and of open clusters to the star-fields of the galactic system. Using an intensifying device in connection with the 100-inch reflector, thus gaining about one magnitude in the photographic limit of the telescope, Mr. Shapley believes he has recorded the faintest stars existing in the globular cluster M 22, and there are indications that the lower limit of brightness has also been approached in the Hercules cluster, M 13. In both of these systems stars of solar brightness appear to be relatively infrequent, but it is of course impossible to say that much fainter dwarfs are entirely absent.

Computations based upon Holetschek's visual magnitudes and upon determinations of distance by Mr. Shapley have yielded the total intrinsic luminosities of 40 globular clusters. The average absolute magnitude is -8.8 ± 0.5, corresponding to 275,000 times the light emission of the sun. An independent method of measuring relative distances of clusters is afforded by the small dispersion in the absolute

magnitudes, the distance in parsecs, d, being related to the apparent visual magnitude, m, by

$$\log d=0.2\ (m+13.8).$$

Results derived from a photographic study of the globular cluster N. G. C. 7006 include a comparison of near and distant systems, a record of new nebulæ, and new data on the form, distance, and dimensions of this very distant globular cluster. A count of 13,500 stellar images on five photographs of N. G. C. 7789 shows the system to be an open cluster, containing something more than 1,000 stars, situated in a rich galactic field. It is about 20 parsecs in linear diameter, if a previous estimate of the parallax ($0''.0003$) be accepted, and most of its stars are brighter than absolute photographic magnitude +6.5.

Cepheid and Cluster Variables.

The discovery of variable stars in the faint globular cluster M 72 was mentioned in last year's report. With the assistance of Miss Ritchie and Miss Mayberry, Mr. Shapley has now derived and published the periods and light-curves of 26 of these stars, which are by far the faintest and most distant variables studied up to the present time. Without exception they are Cepheids of the cluster type, the periods ranging between 0.33 and 0.66 day. The median photographic magnitudes are all near the mean value 16.8; the average range of brightness is 1 magnitude. A new determination gives 83,000 light years for the distance of the cluster.

Since the last report the photometric parallaxes of 9 Cepheid variables of the galactic system have been derived, 5 of them belonging to the cluster type. The variable W Virginis, period 17.113 days, is remarkable for its great distance (20,000 light years), and especially for its high galactic latitude, which is typical of cluster variables but quite anomalous for long-period Cepheids. The period of SW Tauri is very uncommon, falling between the values typical for long and short period Cepheids; the star's position with respect to the galactic plane suggests affiliation with the short-period group.

With respect to the theory of Cepheid variation, Mr. Shapley finds that the observed period-luminosity law requires that the average heat-content per unit-mass should be practically identical for all Cepheids with periods longer than 3 days. Eddington's theory of the radiative equilibrium of a giant star is assumed for the computation of a theoretical period-luminosity curve.

In addition to the 98 new variables reported last year, Miss Ritchie has found 7 new variable stars on Mr. Shapley's photographs of clusters; two of the new variables are in the distant system N. G. C. 7006. Miss Ritchie has also derived a series of magnitudes of Barnard's suspected variable near Messier 11.

PRELIMINARY TEST OF THE THALOFIDE CELL.

Observations of stars with a thalofide cell, supplied by the Case Research Laboratory, have been made with the 60-inch and 100-inch telescopes by Messrs. Benioff and Shapley. Several different arrangements of the apparatus have been tried, using either an electrometer or a galvanometer, the latter with and without an audion amplifier, and large deflections have been obtained in some cases. It seems probable that a special form of cell, with suitable auxiliary apparatus, will prove effective in practice.

STELLAR SPECTROSCOPY.

The systematic stellar spectroscopic work during the year has been carried on by Mr. Adams, Mr. Joy, Mr. Merrill, Mr. Sanford, and Mr. Strömberg. Mr. Duncan and Mr. Hoge have also conducted observations during a portion of the year. Both of the large reflectors have been in regular use and the spectroscopic equipment with the two instruments has been similar in character, a spectrograph with a dispersion of one dense flint prism and a camera of 45 cm. focal length being used at the Cassegrain focus for a large proportion of the photographs. The 18-cm. camera has been employed in the case of a few very faint stars.

Of 1,484 spectrograms obtained during the year, 591 have been made with the 100-inch reflector and 893 with the 60-inch. Numerous photographs of stars brighter than the sixth magnitude have been taken with the 60-inch telescope, while the observations with the 100-inch have been limited almost entirely to stars fainter than the eighth magnitude. The following summary shows the number of spectrograms of stars of different magnitudes taken with the two instruments:

	100-inch.	60-inch.
Brighter than 5.0 visually....	27	171
5.0 to 5.9..................	7	247
6.0 to 6.9..................	50	232
7.0 to 7.9..................	100	167
8.0 to 8.9..................	294	64
9.0 or fainter...............	113	12

A large part of the work with the 60-inch telescope has been devoted to stars under observation for absolute magnitude, while the objects photographed with the 100-inch consist of faint stars of very large proper motion, variable stars of type Md, certain faint Cepheid and Algol variables, and a small number of Novæ and miscellaneous objects.

RADIAL VELOCITIES.

The principal results of the observations for radial velocity may be summarized as follows:

(1) The velocities of 135 stars whose motions are constant have been determined from measurements of 3 or more spectrograms.

(2) The orbits of 5 spectroscopic binaries have been calculated by Mr. Sanford and are ready for publication; of these, 3 show double spectra and thus make it possible to determine the elements of both components. The bright component of the double star OΣ 82 is a spectroscopic binary and is found to belong to the Taurus stream. An interesting binary is Lalande 29330, which belongs to the dwarf K class. The period of 4.3 days is short for stars of this type and the velocity of the center of mass is large, amounting to −60 km. Several new binaries have been discovered, among the most interesting of which are the two long-period Algol variables SX Cassiopeiæ and TT Ophiuchi. The blue companion of α Herculis has also been found to be a binary.

(3) The determination by Mr. Merrill from the bright lines of the radial velocities of 46 stars having spectra of type Md, in addition to those previously known, gives a total of about 90 values for stars of this spectral type.

(4) A tabulation of the results for 83 of these stars with the best known velocities shows that when the solar motion is eliminated 5 have values exceeding 100 km.

(5) The algebraic mean of the velocities for all the Md stars is −23 km. This may be explained as due either to some physical cause which shifts the bright lines toward the violet with reference to the lines which give the true radial velocity, or to a general group-motion of these stars toward the south. If the measurements of the bright lines represent the true radial velocities of these stars, their average motion is the greatest of any class of stars and of about the same magnitude as that of the planetary nebulæ.

(6) The average systematic difference between the values given by the bright and dark lines in these stars is about 20 km.

(7) Spectrograms of 22 stars of type R have been taken by Mr. Sanford with the 100-inch reflector and measurements have been made for radial velocity. Two stars, B.D.+20°5071 and B.D.+23°123, prove to have remarkably high velocities.

Spectroscopic Determinations of Luminosity and Parallax.

The completion during the year of the reduction tables used for the determination of absolute magnitudes from the intensities of spectral lines led the observers to the conclusion that the most reliable value of the mean absolute magnitude of a group of stars, except in the case of the most distant objects, is given by the trigonometric parallaxes rather than the parallactic or peculiar motions. Accordingly, the method adopted for computation of the mean absolute magnitudes has been to use approximate values of the magnitudes based on provisional reduction curves, and to determine the value of the factor by which it

is necessary to multiply the spectroscopic parallaxes in order to secure the best possible agreement with the trigonometric results. Due account was taken of the fact that the errors in the spectroscopic parallaxes are dependent upon the size of the parallaxes themselves. After considerable investigation it was decided to base the reduction upon the four excellent series of trigonometric parallaxes made by the photographic method at the Allegheny, McCormick, Mount Wilson, and Yerkes Observatories. A total of 657 stars of types F, G, K, and M was used in the computation.

The systematic corrections to the approximate absolute magnitudes have been assumed to consist of two parts—systematic errors and errors which are accidental and distributed according to the usual frequency law. As a consequence of this assumption the most probable parallax does not correspond exactly with the most probable absolute magnitude. After the determination of the systematic errors for groups of stars with but small variations in line-intensity and spectral type, the condition of a continuous change of absolute magnitude with these variables is found to hold for all stars except the giants and dwarfs of the later K and M types. Since there appear to be almost no objects of intermediate magnitude among stars of these types, the discontinuity is of little consequence.

The reduction tables for the Cepheid variables and other stars of similar spectral type have been based upon a consideration of proper motions alone, since the measured parallaxes are too small to furnish reliable data. The absolute magnitudes as derived from line-intensities for the Cepheid variables show a marked correlation with the proper motions of these stars.

A comparison of the values of the trigonometric and the spectroscopic parallaxes for the stars used in this reduction shows the following results, the differences being taken directly and without regard to weights:

	No. of stars.	Difference (trig-spec.).	Mean deviation.
Allegheny..........	296	−0."0018	0."0148
McCormick.........	209	−0.0008	0.0193
Mount Wilson......	79	+0.0030	0.0110
Yerkes.............	98	−0.0019	0.0210

The Spectra of Certain Novæ and of the Variable Star T Pyxidis.

The discovery of several stars with the variations of light characteristic of Novæ, made by Harvard observers from a comparison of photographs, has added a number of interesting objects of this character to those already known. Two of these stars have been observed with the 100-inch reflector in addition to Nova Aquilæ of 1918 and the variable

star T Pyxidis, which shows a light-curve similar to that of Novæ and which reached a maximum of light for the third time in 30 years on April 8, 1920. A brief summary of the observations follows:

(1) A photograph of the spectrum of Nova Ophiuchi 1919, taken on November 2, 1919, showed a spectrum characterized by numerous bright bands of hydrogen, calcium, and enhanced iron and titanium. Well-defined absorption lines accompanied the bands and were displaced 5.0 A toward the violet. These displacements and the widths of the bright bands, as in the case of other Novæ, were proportional to wave-length. The radial velocity of the star was found to be +6 km.

(2) A photograph of Nova Ophiuchi taken on July 26, 1920, showed that the spectrum had changed to the nebular type, with strong bright bands and a very weak continuous spectrum.

(3) The spectrum of Nova Lyræ 1919 was photographed on February 5. In addition to numerous bright bands superposed on a faint continuous background, double absorption lines of hydrogen appear, and also a number of other lines due probably to oxygen and nitrogen. The displacements of the components of the hydrogen lines are closely in the ratio of 2 to 1, being −27.5 and −14.3 A, respectively, at $H\gamma$. The oxygen and nitrogen lines are displaced by the larger amount. The spectrum of this star is very similar to that of Nova Aquilæ 1918, 9 days after its maximum of light, and represents what appears to be an intermediate stage in the development of the spectra of Novæ.

(4) Photographs of the spectrum of Nova Aquilæ 1918 have shown remarkable changes and distortions in the form of the chief nebular lines belonging to the disk about the star. These appear to be almost certainly due to internal motions and rotation in this disk, a conclusion already reached by the observers at the Lick Observatory. The continuous spectrum of the star is strong and suggests a development toward the Wolf-Rayet type of spectrum.

(5) Observations of the variable star T Pyxidis made on April 11, 27, and 30 show a remarkable degree of similarity between its spectrum and that of Novæ at an intermediate stage. The bright bands of hydrogen are about 25 A wide and are accompanied on the violet side by complex absorption lines. Numerous absorption lines of oxygen and nitrogen are present, together with the helium line at λ4471. In the interval between April 11 and April 27 the displacement of the absorption lines increased from −22.7 to −28.1 A, a change of much the same order as that found in Nova Aquilæ 1918 during its early history.

(6) The displacements of the successive components of the hydrogen absorption lines appear to show a marked tendency toward a definite integral ratio to one another, the three strongest components having the values −28.1, −21.3, and −14.4 A when reduced to λ4600. A faint component with a displacement of −7.2 A has also been measured.

(7) The very close agreement of the spectrum of such a star as T Pyxidis, which shows repeated maxima of light, with that of Novæ makes it clear that most of the hypotheses of the origin of the latter stars need very decided modification.

(8) A spectrogram of Nova Persei 1901 was secured in October and November with a small spectrograph used at the primary focus of the 60-inch reflector. The emission bands appear of about the same intensity as on an earlier photograph, and the continuous spectrum is seen faintly. In addition, an emission band shows at λ4471, which is fully as strong as that at λ4641. At the date of this photograph Nova Persei had increased considerably in its light.

Miscellaneous Investigations.

(1) The star R Aquarii has been found by Mr. Merrill to contain the bright lines characteristic of gaseous nebulæ superposed upon the normal Md type of spectrum, this being the first case, if Novæ are excepted, in which a star has shown the nebular lines. They do not appear to vary with the change in the star's light, and at a time near minimum the spectrum resembles closely that of a planetary nebula.

(2) A very remarkable change was found to have taken place in the spectrum of *o* Ceti in the interval between December 12, 1919, and January 7, 1920. The star was approaching its minimum of light at this time. The hydrogen lines, which, like the other bright lines in the spectrum, had been narrow and well-defined on the earlier date, suddenly became extremely broad and diffuse and showed a large displacement toward longer wave-lengths. This displacement amounted to about 100 km. relative to the narrow bright lines and is probably in the nature of a widening rather than a bodily shift. At the same time with this change in the hydrogen lines, the helium line at λ4472 made its appearance, being broad and diffuse and showing an intermediate value of the displacement. Both the hydrogen and helium lines are cut off sharply at the edge of the continuous spectrum, in marked contrast to the narrow bright lines due to other elements.

(3) The ninth-magnitude companion of Castor has been found to be a spectroscopic binary of very short period. Both components have a spectrum of type Md, although the characteristic bands are not very strong, and appear to be of nearly equal brightness. This star, together with two others, WB 10^h234 and WB 16^h906, are dwarf stars of the Md type. The star WB 10^h234 has bright H and K lines, and in all three spectra $H\beta$ is the brightest of the hydrogen lines shown on the spectrograms.

(4) The long-period Algol variable TT Ophiuchi has a spectrum composed mainly of enhanced lines like α Cygni, but with bright hydrogen lines which disappear at certain phases of the star's light. Other stars with one or more bright hydrogen lines are 7.1917 Serpentis and RZ Ophiuchi.

(5) A number of observations of stellar spectra with the 10-inch reflecting telescope and an objective prism have been made by Mr. Humason and Mr. Merrill, mainly in the *Hα* region of the spectrum. About 10 or 12 stars have been found to have a bright *Hα* line for which no bright lines were known previously. A remarkable group of objects with bright lines has been found by Mr. Humason near the position R. A. $17^h\ 40^m$, Dec. $-32°$, in addition to others already known in this region.

(6) The following objects were observed for radial velocity by Mr. Sanford with a small spectrograph at the primary focus of the 100-inch telescope:

N. G. C.	Rad. vel.	Remarks.
1514.....	+11	Stellar nucleus of faint planetary.
1647.....	+66	Open cluster; measures on star No. 8.
2245.....	+ 8	Stellar nucleus of cometary nebula.
2682.....	+13	Open cluster; measures on stars Nos. 81 and 261.

STELLAR INTERFEROMETER.

As set forth by Professor Michelson in the Astrophysical Journal, vol. 51, 257–262, 1920, Mount Wilson Contribution No. 184, one of the lines of investigation which seemed sufficiently promising to warrant a preliminary trial was the measurement of the size of stars by the interference method. As shown in this article, the possibility of such an application of the interferometer, aside from mechanical difficulties (some of which proved not entirely negligible) is determined by the effect of atmospheric disturbances on the appearance of the interference fringes.

The results of actual trials had shown not only that interference fringes were clearly visible with a base-line of the full aperture of the 40-inch refractor at Yerkes Observatory, of the 60-inch reflector and the 100-inch reflector at Mount Wilson, but also that exceedingly accurate measurements (such as the determination of the separation of close double stars, etc.) could be made even when the seeing was so poor that the usual observations were impossible. The application of the method to the measurement of the system of Capella is described below.

In explanation of so unexpected a result, it may be suggested that in bad seeing, when using the whole aperture of the objective, there is an integrated effect of the light-waves meeting in all possible phases, which tends to obliterate the details of the diffraction-pattern of the star-image, but that when two light-pencils are selected at opposite ends of a diameter, the result is not an integration, but a mere displacement of the diffraction-pattern, sufficiently small for the eye to follow. Such

a displacement, which has not yet been looked for, would be of the order of the distance between the fringes—a very small quantity.

In view of these encouraging results, it was decided to attempt to observe interference with an interferometer consisting of two plane mirrors, separated by a distance of 20 feet, which reflect the light from the star to two other planes (about 4 feet apart), whence the two pencils proceed to the 100-inch surface, and thence to the convex Cassegrain reflector and the eyepiece, in the focus of which the two pencils unite, producing, under proper conditions, the interference fringes to be observed.

A preliminary trial showed that the adjustments provided for the mirrors were much too coarse, and these were accordingly remodeled. Further, instead of attempting to produce equality in path (with an ordinary accuracy of a ten-thousandth of an inch, which is necessary if the interference is to be observed in white light), an adjustable double wedge of glass made it possible to vary the optical path gradually and continuously, until the required condition was fulfilled. A plane parallel plate of thickness equal to that of the double wedge is placed in the path of the other pencil, and by appropriate inclination proves valuable in securing the coincidence of the two images.

A trial of this arrangement was made on Vega on August 6 by Mr. Pease, and interference fringes were observed with a base of 18 feet, seeing 4 on a scale of 10, magnification 1,600. Fringes were also found in white light. The observations were confirmed by Mr. Sherburne.

On August 8, with the outer mirrors about 7 feet apart, and with the aid of a direct-vision prism in front of the eyepiece, Mr. Pease found fringes, which were then observed by Professor Michelson. Fringes in white light were also found. Observing Vega again on August 9, fringes were seen in white light by Messrs. Hale, Michelson, and Pease (who found them) with a base of 12 feet, but, owing to an error in adjustment, they were not observed at a greater distance.

The appearance of the interference fringes was about as good with the maximum base of 18 feet as with one of 7 feet, which seems to indicate that it should be quite feasible to obtain interference with a base of 100 feet or more. If any of the nearer stars, say with a parallax of $0''.2$, are as large as the sun, their disks would subtend an angle of about $0''.002$, which would be manifested by a disappearance of the interference fringes if the base were 200 feet long. Recent calculations by Professor Eddington and by Mr. Shapley, based upon provisional values of the surface brightness of a star, indicate that some of the late-type giants may have diameters of the order of 20 times the value specified, which would render the conditions much more favorable. In addition to the determination of stellar diameters, an interferometer with a long base could also be used for measurements of double stars whose separations are very small—of the order of $0''.001$, for a base of 200 feet.

Interferometer Observations of Capella.

Part of the time from December to April was devoted by Mr. Anderson to an application of Michelson's interferometer method to the measurement of the spectroscopic binary Capella. The method, first described by Michelson in 1890–91 and employed by him in a determination of the diameters of Jupiter's satellites, has not since been applied to astronomical problems. Preliminary trials by Professor Michelson having shown that atmospheric disturbances probably would not offer serious interference, it was decided to test the method with the 100-inch telescope, and the problem chosen was the measurement of close double stars or spectroscopic binaries.

In the ordinary use of a telescope, light from a celestial body is allowed to fall on the entire objective; when a telescope is used as an interferometer the light traverses only two relatively small areas of the objective, which are usually rectangular in shape and symmetrically situated with respect to the center. If the object observed is a single star of exceedingly small angular diameter, the observer sees in the focal plane a series of perfect interference fringes. If, on the other hand, the object be a uniformly luminous disk of angular diameter a, the distinctness of visibility of the fringes will be poor if the distance between the two areas of the objective is in the neighborhood of λ/a, and indeed will be zero if this condition is exactly fulfilled. If the object be a double star whose components are separated by an angular distance a, the fringes will be invisible when the distance between the areas is $\lambda/2a$ and the line joining the areas is parallel to the line joining the two stars, provided the two component stars are equally bright. If the components are of unequal brightness the visibility will be a minimum under the same conditions.

The interferometer, consisting of a tube about 27 inches long, having two rectangular apertures of variable separation at one end and an eyepiece at the other end, was mounted at the Cassegrain focus. It could be rotated about its own axis for determination of position angle. It was at once found that Capella showed the disappearance of the fringes to be expected in the case of a double star of nearly equal components, and a series of four complete and two incomplete observations was secured between December 30, 1919, and April 23, 1920. These observations show that both angular separation and position angle can be measured to an accuracy of about 1 per cent. It was also found that seeing as poor as 1 on a scale of 10 is not very harmful, though with better seeing the observations are easier to make. Since the spectroscopic elements of the system of Capella are already well known, the present observations give us a good knowledge of the true orbit, the distance, and the mass of Capella. The semi-major axis of the true orbit is 0."05249 and the parallax 0."0600. The masses of the compo-

nents are 4.62 and 3.65 times the solar mass. The observations show the following residuals when compared with the adopted orbit:

Date, G. M. T.	O–C.	
	Distance.	Pos. angle.
1919, Dec. 30.6....	0."00000	....
1920, Feb. 13.6....	−0.00003	+0.°4
Feb. 14.6....	+0.00004	0.0
Feb. 15.6....	0.00000	−0.9
Mar. 15.6....	0.00000	−0.4
Apr. 23.6....	....	−0.2

As a further test of the precision of the method, a longer series of observations should be secured as soon as possible.

VELOCITY OF LIGHT.

It is estimated that the uncertainty in the value of this fundamental constant is of the order of 30 km., or 1 part in 10,000. When determined by the method of Foucault with the revolving mirror, the result depends on the measurement of three quantities, namely, the distance between the stations, the speed of the revolving mirror, and the angular displacement of the returning beam by the revolving mirror. The first and second of these quantities can probably be measured to 1 part in 250,000, possibly to 1 in 1,000,000; but this can not be affirmed of the angular displacement. This difficulty may, however, be eliminated, or rather transferred to the construction of a revolving mirror with angles of 90° or 135°, which has been found possible to an order of accuracy of 1 in 1,000,000. Since the mean of all four (or eight) angles is the determining factor (the effect of these errors being merely to broaden the return image by a very minute quantity), the actual error in the resulting determination due to this source will be still less.

The method of observation adopted by Professor Michelson is to give the mirror such a speed that the returning light is received on the next succeeding face of the mirror, the image of the slit source being kept on the cross-hair of the eyepiece. The speed of the mirror is measured simultaneously by optical comparison with a tuning-fork, whose rate is ultimately ascertained by comparison with an astronomical clock. Measurement of the zero is eliminated by alternate clockwise and counter-clockwise rotations. It was found possible to obtain a speed of 1,500 to 2,000 revolutions per second. With a speed of 1,000 per second and a rotation of 90°, the required distance between the stations is 37.5 km., which is somewhat less than that between the Mount Wilson Observatory and Mount San Antonio.

With a view to testing the feasibility of the method, and especially to investigate the intensity and the sharpness of the return image, a preliminary trial was made, using the roof of the Chemical Laboratory of the California Institute of Technology for the home station and a pier erected at the base of Mount Lowe for the distant station, the distance being a little over 4 miles. The result was very favorable as regards intensity, but the seeing was never satisfactory, so that the return image was not sufficiently sharp to measure with the required degree of accuracy.

A second preliminary trial is now in progress, with Mount Wilson as the home station and the Puente Hills for the distant mirror, the distance being something over 16 miles. It is hoped that the increased elevation will give a much clearer atmosphere, with greater steadiness and sharpness of the return image.

It may be noted that in the first trial the return image was viewed upon a fairly bright background caused by the diffuse light due to the direct illumination of the revolving mirror. In the present trial the light is returned to the opposite face of the mirror, which is entirely dark, thus increasing very considerably the visibility of the return image. It may also be mentioned that an incidental advantage of the octagonal form of the revolving mirror is an eight-fold intensity over that from a single face.

PROFESSOR KAPTEYN'S INVESTIGATIONS.

Professor Kapteyn, Research Associate of the Observatory, has continued his investigations of the arrangement of the stars in space. A first approximation for the solution of this problem was given in Groningen Publications, No. 11, and in the Proceedings of the Amsterdam Academy, March 28, 1908 (p. 626). In this first attempt the evident differences depending on galactic latitude were neglected and only the average stellar densities at different distances from the Sun were derived.

A second though still provisional approximation has now been made in collaboration with Dr. van Rhijn and published in Contribution No. 188. In this paper the different galactic latitudes are treated separately, but the differences in galactic longitude arising from the star clouds of the Milky Way are still disregarded.

The investigation leads to: (*a*) A more complete knowledge of the luminosity curve. This has now been determined for a range of 22 magnitudes, for 18 of which the accuracy must be high. The curve can be represented by an error curve with astonishing closeness. The median (or average) luminosity of the stars is found to be 2.9 magnitudes fainter than that of the Sun. (*b*) The change of star-density with distance from the Sun for different galactic latitudes. Repre-

sented graphically by a figure showing a section of the stellar system through the center at right angles to the plane of the Milky Way, the results give lines of equal density which are elliptical in form. For a density 1/200 of that near the sun the longer axis lying in the Galaxy is about 8 times the shorter axis towards the pole.

In another investigation, now nearly ready for press, the accuracy attainable in results such as these has been investigated. The determination of the arrangement of stars in space, as given in Contribution No. 188, rests mainly on a knowledge of (*a*) the luminosity curve and (*b*) the curve giving the total number of stars, N_m, for the different apparent magnitudes m. Observations do not give these curves completely but only to certain limits. The question is whether these limits are sufficiently extended for the purpose.

For the luminosity curve (*a*) it appears that the limit now reached will be sufficient for the investigation of the arrangement of stars in space so long as our observations do not extend below the thirtieth apparent magnitude. It will therefore satisfy our wants for many years, perhaps many centuries.

For curve (*b*), on the other hand, our observational data are not nearly what could be wished. For values of N_m down to magnitude 17 visual, which is well within the limit of the Mount Wilson survey of the Selected Areas, the agreement with an error curve is here also remarkably close. If we assume that the error curve represents equally well the total numbers of stars for all magnitudes fainter than 17.0, then the present data will be sufficient for a fairly good determination of the distribution of the stars in high galactic latitudes up to distances well beyond the median (that is, the distance within which half of all the stars are to be found). For a reasonably satisfactory determination of the median in the direction of the Galaxy, however, our knowledge of the values N_m must be extended to stars of about the twentieth magnitude. If we can not assume that the analytical curve derived from the observed values of N_m applies also for m fainter than 17, the problem becomes much more difficult, and, in a certain sense, insoluble

Nevertheless, a very probable limit of distance can be assigned up to which the densities can be calculated, although this limit is not yet fully determined. In all probability it will be found to be considerably in excess of 10,000 parsecs. Corresponding limits will also be derived for the cases in which the total numbers of stars down to $m=18$, 19, 20, and 21 are known.

A first attempt has also been made to determine the distribution of the stars in the Milky Way cloud between β and γ Cygni. For a reliable determination, however, counts of the stars down to the twentieth visual magnitude will be required.

PHYSICAL LABORATORY.

INSTRUMENTS.

The 500-k. w. direct-current generator set, mentioned in last year's report, was delivered by the General Electric Company in March. The set includes generator, synchronous motor, and exciter, the three being direct-connected. The motor receives current at 2,200 volts, the Southern California Edison Company supplying a special connection with its downtown lines to provide for this additional load. The generator is rated to supply 4,000 amperes at 125 volts, but the adjustment of its field permits a range from 15 to 150 volts, a very useful latitude for the service required in the laboratory. The three machines are mounted on a common base which rests on a concrete pier, all rigid connection with the building being avoided. An alteration of the laboratory building, involving the addition of a space 11½ by 18 feet between this and the adjoining optical shop, together with all work connected with the mounting of the generator set and its switchboard, was taken care of by our Construction Division, while the electrical work was done by the H. L. Miller Company. Massive copper cables, aggregating 5,000,000 circular mils, are laid in ducts beneath the floor from the generator to a convenient point in the laboratory. The trials made of the installation, in various experiments since its completion in June, have shown highly satisfactory operation in every respect.

The construction, beneath the floor of the optical shop, of a concrete-lined tank of about 5,000 cubic feet capacity was completed during the winter. Tests as to the use of water in cooling the solenoid magnet indicated that difficulties from electrolysis would result. It was, therefore, deemed best to provide for cooling by kerosene, this to be cooled in turn by the water in the tank. A system of pipes, forming vertical grids, was built up in the central part of the tank and kerosene will be circulated through these and to the apparatus by means of a pump.

A trial solenoid, calculated to give a field of about 40,000 gausses, with a tubular opening through the center, has been wound of bare copper tape, the successive turns being insulated by cords, which provide interstices through which the cooling kerosene may be forced. The housing to contain the kerosene has also been made, but press of other work in the machine shop during the summer has delayed the assembly of the apparatus.

Within the solenoid a tube electric-furnace in a vacuum-chamber will be inserted. This will allow the examination of the Zeeman effect, both direct and inverse, for those lines which are especially strong in the furnace and often faint in other sources. High precision of measurement may be expected to result from the intense field of the solenoid in combination with the remarkably sharp lines produced by the furnace when operated in vacuum at moderate temperatures.

For the study of emission and absorption spectra at very high temperatures, a tube furnace has been constructed of the type regularly used in the laboratory, but with water-cooled contact-blocks of large size designed to carry especially heavy currents. The furnace-tube is protected by a large water-jacket. This furnace has proved entirely suitable for the purpose intended, long runs at temperatures above 3,000° C. being possible, while but a few minutes are required to put a fresh tube in position.

An optical pyrometer of the disappearing-filament type, made according to the Morse patent by the Leeds and Northrop Company, has been purchased and has proved useful in furnace work where focusing on the incandescent object was desired.

A large condenser, of about one microfarad capacity, charged from a 26,000-volt transformer, with rectifying device, was constructed for experiments on the spectra of explosions.

A 2-inch concave grating which the laboratory has owned for several years has been mounted for use with parallel light in a small wooden spectrograph. This instrument is designed for use as an auxiliary dispersion piece for work with the interferometer in the red and infrared. With it the interference spectrum of iron has been obtained in good focus from λ5500 to λ8000 on a scale of about 19 A per millimeter. For the extension of wave-length standards into the region of longer wave-lengths this instrument is proving very useful.

A set of six interferometer plates of crystalline quartz has been made for the laboratory in the optical shop. The figuring is now so nearly complete that the plates are ready for final testing under actual working conditions. They will form a valuable addition to our present equipment, especially now that the fused-quartz plates are in use on the mountain.

To produce the monochromatic light necessary in many optical tests and to supply a very useful working standard of wave-length, a Cooper-Hewitt mercury-vapor lamp has been installed in the laboratory. Its great intensity, uniformity, and convenience have made it practically indispensable.

ELECTRIC-FURNACE INVESTIGATIONS.

The study of the very rich spectra of the rare-earth metals has been taken up by Mr. King with the electric furnace. In addition to those previously made for cerium, spectrograms at various temperatures, and in some cases with different compounds, have been made for zirconium, lanthanum, neodymium, and yttrium. Though the examination of these plates is incomplete, the distinctive features of furnace spectra are found to be well represented, a group of low-temperature lines being present, with other groups appearing as the temperature is raised. Many strong lines require very high furnace temperatures before they appear.

Supplementary photographs of the iron and manganese spectra have been made, especially in the infra-red. In the visible region, long exposures at low temperatures were used to determine the lines first radiated by the vapor. For this work, current from the new 500-k. w. generator was frequently used on account of the close adjustment of the voltage which the control system of the generator permits. The photographs of the barium furnace spectrum already supplied to Professor F. A. Saunders for use in tracing the various series of this element has been supplemented by photographs of selected regions taken with an iron comparison spectrum. A further study of the absorption spectra of calcium and iron was made by placing a plug at different points in the furnace-tube and observing the effects of balancing emission and absorption, which often caused lines to become invisible in the photographs, although they were strongly radiated by the vapor.

An investigation was made of the possible effect of a potential difference at the ends of the furnace-tube filled with ionized vapor, the question having been raised as to whether the sensitive high-temperature lines (class III) require conditions equivalent to those of a low-tension arc instead of simply a higher temperature. The method used was to reduce or eliminate the potential difference while the high temperature was maintained, and compare the spectrum with that emitted at the same temperature with the usual operation of the furnace. A reduction of the potential to which the vapor was subjected was produced by vaporizing iron in an insulated tube inside the tube carrying the heating current, and also by the use of direct current from the new generator, by means of which the momentary high values of the potential occurring with an alternating current were avoided. By the latter method the test spectra of high-temperature lines were produced with a potential difference of only 0.5 volt per centimeter. Spectrograms were also made with no current in the tube. The tube, protected by a jacket, was heated by the current, which was then broken, the spectrum being photographed as the tube slowly cooled. This method with no current was supplemented by experiments in which an insulated tube was heated by an external arc. In both cases the spectrum was the same as that of the regular resistance furnace at the same temperature. While it is obvious that some current may be conducted by the ionized vapor of the resistance furnace, the experiments have shown that for the temperatures used in the classification of lines the low potentials required are ineffective in producing any change in the spectrum.

The production of the "cyanogen" band at $\lambda3883$ in absorption under high dispersion was undertaken by Mr. King to supply data for the work of Mr. St. John on the wave-lengths of the solar lines belonging to this band. Since unsymmetrical structure may influence the measurements, it is desirable that absorption lines from a laboratory

source should be measured, rather than the emission lines of the carbon arc. The experiments required the use of a plugged tube in the furnace at atmospheric pressure and at very high temperatures in order to give sufficient continuous ground in this region. The long exposures needed for the high dispersion and the slow plates imposed a severe strain on the furnace, and after some partially satisfactory results were obtained, the special furnace described above was constructed. Strong photographs were then obtained without difficulty, temperatures of 3,200° C. and higher being employed. A set of these plates with iron-arc comparison is now ready for measurement.

An examination under high dispersion of the λ3883 band in emission for the furnace and arc spectra showed clearly an effect which had been noticed on spectrograms of lower dispersion, namely, that the component lines of the band do not behave alike when the excitation is altered. Lines belonging to certain series are relatively stronger in the furnace than in the arc, and reverse in the furnace more easily than lines of other series which are strong in the arc. Spectrograms of moderate dispersion indicate that the same condition prevails in the band at λ5165, and it is probably general in the carbon spectrum. This phenomenon has direct application to questions involving the wave-length of these band-lines in different sources, since, if there is an analogy with the line-spectra of metals, the lines relatively strong in the furnace are less subject to variation of wave-length under conditions which produce displacements. An effort will be made to determine how far the effect is a result of temperature difference.

STANDARDS OF WAVE-LENGTH.

The interferometer program for determination of standards of wave-length in the spectrum of iron has been completed by Mr. Babcock for the region λ3370–λ6750 and the results are now being prepared for publication. About 610 iron lines have been observed in this interval, many of them on a large number of photographs. Various orders of interference have been used and much care has been given to the elimination of mistakes. The discussion of this observational material is not complete, but it is apparent that for good lines the accordance with other observers is very satisfactory, while in the case of sensitive lines our interferometer measures show clearly a systematic difference when compared with observations which are influenced by pole effect.

The extension of our wave-length standards toward both shorter and longer wave-lengths is in progress. Fifty-two photographs of the iron-arc spectrum have been taken with the interferometer in conjunction with the large quartz spectrograph, covering the region λ2270–λ4500. The final reduction of these plates is not yet complete, but the best of them have been measured. In the other direction five photographs have been made of the interference spectrum of iron from λ5500 to about λ8000. These have been measured and reduced, and

will be supplemented by other plates as rapidly as possible. It is not planned at present, however, to extend our system beyond λ8500, on account of the extremely long exposures required beyond that point with the present photographic appliances.

In addition to the interferometer measurements, the grating has been used direct for the determination of standards of wave-length by Mr. St. John, the regions covered being the same. Owing to the higher dispersion in the grating method, the number of lines obtained with it is much larger. The agreement is in general so satisfactory that obvious errors may be eliminated. Both series of measures are being prepared for publication.

OTHER OBSERVATIONS OF WAVE-LENGTH.

In addition to the work noted above on standards of wave-length, considerable attention has been given by Messrs. St. John and Babcock to the determination of certain other wave-lengths for special purposes. As noted in last year's report, a study had already been made of the supposed variability of the absorption lines of oxygen present in the earth's atmosphere, with entirely negative results. During the year the wave-lengths of many of the lines in the *a* group have been measured in terms of the secondary standards of wave-length, both with gratings and with the interferometer. The observations are being made in Pasadena as well as on Mount Wilson, using both types of instrument at each place. It is hoped that when this work is completed we shall have available a group of lines whose wave-lengths can be relied upon with certainty to the thousandth of an angstrom unit. They will prove of extreme value in many observations on the solar spectrum, because they will obviate the necessity of securing a reliable comparison spectrum. The work is being extended to include high-precision measurements upon the B-group of oxygen lines and also upon certain lines due to water-vapor.

On account of their extreme sharpness, absorption lines in the spectrum of iodine-vapor are of special importance in precision spectroscopy. The question of transferring the primary standard from the red line of cadmium to one of these iodine lines is receiving serious consideration at present, and furthermore, selected lines of accurately known wave-length may serve as highly valuable fiducial points in the spectrum, since they may be photographed simultaneously with another spectrum. The study of the iodine spectrum has accordingly been continued at intervals during the year, special attention being given to lines which coincide with metallic arc lines. Thirty-one of these pairs, which are as nearly monochromatic as any known spectral lines, are under observation. For more than half of them it is thought that the incomplete observations now at hand establish their absolute wave-lengths with an uncertainty of 1 part in 5,000,000, and it is hoped that when the program is finished this accuracy will be exceeded for most of the lines.

The importance of work upon absorption lines of oxygen and iodine will readily be recognized in connection with such problems as the absolute determination of wave-lengths in the solar spectrum, and, for example, in the search for indications of the Einstein effect. Our aim is to supply four convergent lines of evidence bearing upon this fundamental question, as follows: (1) simultaneous exposures to the solar spectrum and that of the iron arc, using high-dispersion plane-grating spectrographs; (2) direct determinations of solar wave-lengths with the interferometer, using the iron-arc standards; (3) direct observations of solar wave-lengths in terms of atmospheric lines upon the same plates, using both grating and interferometer, no comparison spectrum being employed; (4) use of the iodine spectrum in place of the atmospheric spectrum in (3).

It is to be borne in mind that the accurate determination of solar wave-lengths must be supplemented by detailed knowledge of the terrestrial values for the individual lines concerned before valid conclusions can be reached regarding such a problem as the Einstein effect. To this end a laboratory study of the spectra of certain elements which are of special importance in the sun is in progress. The interferometer is being used for measuring wave-lengths in these spectra in terms of secondary standards from the iron spectrum. On account of the possibility of disturbing influences like the pole effect in the arc, it is necessary to proceed with caution, applying tests for any possible variation of the terrestrial wave-length which may be dependent upon the kind or condition of the source employed. Up to the present about 25 lines for barium and lanthanum have been measured on a number of interferometer plates, with 16 lines for strontium. A few observations have been made on some of the lines of calcium and nickel in the red part of the spectrum.

PRESSURE EFFECT FOR ARC SPECTRA.

An accurate knowledge of the effects of pressure on wave-lengths of special lines will prove of great assistance in correctly interpreting observations of the solar spectrum. Physicists and astronomers who have studied the sun for evidence of the Einstein effect have recognized this in selecting the cyanogen band at λ3883, chosen because it was supposed to have no pressure effect. A recent paper announces, however, that this band has an appreciable negative pressure-displacement, so that conclusions based upon its wave-length in the sun must be suspended until its pressure effect is finally determined.

In the case of iron, the pressure-displacements obtained by Gale and Adams for lines of groups *a* and *b* of the Mount Wilson classification have been satisfactorily confirmed, but a further examination of the sensitive lines, in which extreme care is taken to avoid the introduction of pole effect, is now required. The means and time are now at hand for effectively attacking these problems in our laboratory, and the observations are already in progress. The interferometer is being used

for this work, the pressure ranging from a few millimeters of mercury up to one atmosphere. The method of simultaneous exposures, which has proved so useful in our previous experience with both gratings and interferometers, will be followed in this exacting work.

SPARK SPECTRA.

For his work on the spectra of electrically exploded wires, Mr. Anderson has built a condenser of about 1 microfarad capacity, which can be operated at 25,000 volts. Brilliant sparks of extremely violent character are produced by the discharge of this condenser, especially when the inductance in the circuit is kept very low. On account of its great capacity, the condenser is charged from the secondary of a 5-k. w. high-voltage transformer through a mechanical rectifier. Messrs. Anderson and Babcock have together used this apparatus with the 15-foot concave-grating spectrograph to secure photographs of the spark spectra for iron, titanium, chromium, nickel, and vanadium over the region λ3000–λ7200. The plates have been studied by Miss Keener, who has classified the lines as to general character, including sharpness, symmetry, etc. Since this source of light presents the most extreme type of spark spectrum thus far obtained in our laboratory, the photographs form a valuable reference map for comparison with other sources.

SPECTRA OF EXPLODING WIRES.

During the year Mr. Anderson has been engaged principally in the study of the spectra of electrically exploded wires. The investigation is a first attempt to imitate as far as possible in the laboratory the conditions which must exist when a meteoric particle moving with very high velocity encounters a resisting medium such as the atmosphere of the sun or a star. The large amount of kinetic energy possessed by the particle is transformed into heat, undoubtedly in a very short time. This results in a very rapid vaporization of the materials constituting the particle itself. In order to produce a very rapid vaporization of a substance in laboratory experiments, the discharge of a large condenser, charged to as high a voltage as possible, was employed. The substance to be vaporized—metals in the present case—was inserted in the condenser circuit in the form of a fine wire. When the discharge takes place the vaporization is so rapid that it can be described only by the word explosion. If the gases formed in such an explosion are confined slightly, the spectrum is continuous with the lines of the substance composing the wire appearing in absorption. The spectrum of iron produced in this way was studied from λ2200 to about λ6600. All the lines except the pronounced enhanced ones are present. The intrinsic brightness of the explosion was found to be of the order of 100 times that of the solar surface, corresponding to a black-body temperature of 20,000° C.

The preliminary work was done with a condenser of 0.4 microfarad capacity, charged from a 26,000-volt transformer, the current from the secondary of the transformer being rectified by a mechanical device. Later a condenser of approximately 1.0 microfarad was constructed and used with the same transformer. With the larger condenser the brightness of the explosion was increased very much in the region of longer wave-lengths. There did not appear to be a corresponding increase in the region of short wave-lengths, suggesting that as the amount of energy is increased, the source becomes redder.

The work will be continued, using higher voltage, and, if possible, more energy in the discharge. It is also planned to study the explosions in gases other than air, such as hydrogen and perhaps helium. Since this method makes it possible to produce in the laboratory spectra similar to those of the sun and the stars, it is likely to be of considerable importance in astrophysical investigations.

AIR LINES IN SPARK SPECTRA.

Since the last report some additional work has been done by Mr. Merrill on the air lines given by metallic sparks in the red and infra-red. By operating the spark in an atmosphere of oxygen, several identifications of oxygen and nitrogen lines by previous observers using vacuum-tubes were confirmed, and the doubtful identification of $\lambda 7157$ with oxygen was strengthened.

DISCHARGES IN HIGH VACUA.

Miss Carter has resumed experiments on the spectra of discharges in high vacua, using now the brief, arc-light discharge which takes place between metallic electrodes when a high potential, with condenser, breaks down the resistance of the vacuum. The characteristics of such spectra are little known.

Using a source of this type to produce lines of very short wave-length, Professor Millikan observed a notable strength in the extreme ultra-violet. This result made it desirable to examine the range of spectrum usually observed, and Miss Carter has now completed the observations for the spectra of iron, titanium, calcium, cadmium, and magnesium. The lines obtained greatly exceed in number those recorded in previous observations with the high-vacuum spark. A detailed study has not yet been made, but the spectra resemble closely the regular spark spectrum, except in the case of iron, for which a similarity to the spectrum of the core of the arc seems to prevail.

CONSTRUCTION DIVISION.

DRAFTING AND DESIGN.

The chief work of the drafting department during the year has been the design of a 20-foot stellar interferometer and compensator; an observing platform for the 134-foot Cassegrain focus of the Hooker

telescope; large solenoid magnet and its auxiliary cooling-tank and coils; a small star-diameter machine; and an 8 by 10 differential measuring-machine for stellar parallaxes and proper motions. Miscellaneous work has included designs for additions to the observing platform at the Newtonian focus of the Hooker telescope, adapters for plate-holders and spectrograph, cloth-covered extension of the 100-inch tube, binocular eyepieces for measuring-machines, mirror supports for velocity-of-light apparatus, many small attachments to existing instruments, and many illustrations and charts.

OPTICAL SHOP.

A 36-inch concave mirror of 900-foot focal length and a 22-inch plane were figured for the velocity-of-light apparatus. Other work of the year included two 9-inch and six smaller plane mirrors, six quartz interferometer plates, two 2.5-inch plane parallel plates, a 10-inch lens for the finder of the Hooker telescope, and 15 grating-plates from 4 to 10 inches square. The opticians also assisted in the construction of a 2-foot polishing-machine, an edge-grinder, a testing arrangement for 4-inch plates, and a revision of the 12-inch testing-stand so as to render it universal.

The mirrors of the telescopes on Mount Wilson have been burnished at regular intervals.

INSTRUMENT SHOP.

About half the time of the instrument shop has been devoted to the Hooker telescope and its accessories, including the construction of the 20-foot stellar interferometer, smaller interferometer, observing platform for work at the 134-foot Cassegrain focus, 8 by 10 plate-carrier for the Newtonian focus, 4 by 5 and 5 by 7 plate-holders, and much work on the Cassegrain spectrograph, temperature-control apparatus for the 100-inch mirror, coudé mechanism, tube extension, mountings of Cassegrain and Newtonian mirrors, upper observing-platform, ladders, instrument cabinets, besides many miscellaneous items. Other work included the construction of three 4 by 10-inch machines for measuring spectra, improvements in the 10-inch photographic refractor, special arcs for the laboratory, improvements of the cœlostat and spectrograph of the Snow telescope, grinding and polishing machines for the optical shop, installation of 500-k. w. motor generator, large solenoid magnet and cooling-plant, velocity-of-light apparatus, earth-tide apparatus, and miscellaneous equipment and repairs.

RULING MACHINE.

Several gratings have been ruled during the year, some of which give excellent resolution and unimportant ghosts, but show considerable diffuse light due to a series of short spectra. These probably result from some obscure source of periodic error, which is now being sought by Mr. Jacomini.

BUILDINGS AND MISCELLANEOUS CONSTRUCTION.

No new buildings have been constructed on Mount Wilson, but considerable work has been done there in connection with the erection of the Cassegrain observing-platform and other accessories of the Hooker telescope. The dome of the 60-inch telescope has been repainted, much brush has been cut for fire protection, and the usual work of clearing and maintaining the mountain road has been carried out under the direction of Mr. Jones, superintendent of building construction. In Pasadena a wing has been added to the physical laboratory for the 500-k. w. motor generator-set and a large tank has been built under the optical shop for the cooling-coils of the solenoid magnet. The construction of piers for the velocity-of-light apparatus and its installation at several different sites should also be mentioned.

Mr. Dowd, engineer in charge of the Mount Wilson power-plant, has completed the electric wiring for the Cassegrain observing-platform of the Hooker telescope, installed the refrigerating plant for the 100-inch mirror, and done much other wiring and work of repair.

NUTRITION LABORATORY.[1]

FRANCIS G. BENEDICT, DIRECTOR.

In common with all educational and research institutions, the Nutrition Laboratory has been obliged to curtail its activities, owing to the threefold effect of increased cost of maintenance, depletion of staff by important withdrawals, and the almost prohibitive cost of normal human subjects for observational purposes. Under these conditions and with a budget remaining constant for nine years, material rearrangements of plans have been imperative. Larger projects, such as the study of muscular work, and particularly the extended alcohol program, to which a certain proportion of the Laboratory activities have been devoted, necessarily had to suffer. That the scientific output has not greatly decreased in spite of these handicaps is due solely to the interest, loyalty, and capacity for work shown by the staff members. At a time when inefficiency and non-production are too generally the rule, this capacity for increased accomplishment is all the more to be commended. While the two factors of increased efficiency and assumption of new responsibilities on the part of practically every staff member have in the past offset to a large degree the three great handicaps, this year, with the withdrawal of two senior members of the staff, Professor H. Monmouth Smith and Mr. Warren E. Collins, readjustments can be made only with the greatest difficulty and a curtailment of scientific activity is inevitable.

ADDITIONS TO EQUIPMENT.

Static control recorder.—It is common clinical practice to test the stability of a patient's coordinating mechanism by having him stand with eyes closed and then noting roughly the amount of sway. An obvious refinement in such a test for static control is to provide a graphic record, traced on smoked paper by a stylus extending from a helmet worn by the subject. A member of the Laboratory staff, when visiting Colonel Melville, of the Army Medical School, London, observed such a technique. Dr. Miles used a similar arrangement when working with the aviation candidates in 1917. An attempt to convert such graphic records into a quantitative score gave no satisfactory results, except for a simple statement of the maximum distance covered in the movement, forward, backward, and sidewise.

On the basis of previous experience, an apparatus was devised employing four movement-adders. Each adder accumulates the amount of sway in one particular direction, and the total for that direction can be read in millimeters of body movement. The action is noiseless and can be started or stopped instantly. The apparatus provides also a

[1]Situated in Boston, Massachusetts.

graphic record, which serves as a check upon and a rough analysis of the quantitative score. This test is a very easy one to give and will probably be of considerable significance in determining the effects of small amounts of alcohol and in measuring the effects of nutritional factors and such conditions as fatigue.

Portable respiration apparatus.—The increasing use by clinicians of the study of the gaseous exchange, particularly the oxygen consumption, has resulted in an unexpected interest in the portable or, more properly speaking, transportable respiration apparatus referred to in the annual report for 1918. Need for a truly portable apparatus of relatively simple design, which would be primarily adapted to clinical if not, indeed, for office use by physicians, led to a modification of the earlier apparatus and the construction by our mechanician, Mr. Collins, of several of these according to the new design.

Minor apparatus.—The increasing use of motion pictures to study and record not only scientific technique but physiological processes has resulted in the purchase of a projection machine to supplement our excellent motion-picture camera.

COOPERATING AND VISITING INVESTIGATORS.

Dr. Eliott P. Joslin, with his personal assistants, Dr. Albert A. Hornor and Miss Anna Holt, has spent much time at the Laboratory in preparing the report of the large amount of work on metabolism in diabetes mellitus.

Dr. Fritz B. Talbot contributed to the preparation of the final report on the metabolism of children from birth to puberty.

Dr. J. Arthur Harris has again kindly consented to review statistically several important metabolism problems, and a paper is now nearing completion.

Mrs. Cornelia Golay Benedict, at the urgent demand of a number of physicians, has continued her calorimetric studies of extra foods. A third report of her results is being prepared.

The unusual success of the research on the energy requirements of large animals with the new respiration apparatus at the New Hampshire Agricultural Experiment Station in Durham has resulted in arrangements whereby Professor E. G. Ritzman devotes an even larger proportion of his time to this work, and, with the counsel of Director John C. Kendall, experimental activities at that station are greater than ever.

Dr. Paul Roth, a frequent visitor at the Nutrition Laboratory and one of the co-authors of the report on undernutrition (Publication No. 280), has most helpfully cooperated by making an exhaustive clinical test of the new portable respiration apparatus in his laboratory at the Battle Creek Sanitarium, Battle Creek, Michigan.

Dr. G. H. de Paula Souza spent two months at the Laboratory, cooperating in researches with Professor Miles and contributing largely, in many ways, to the scientific discussions of staff members. His active interest in human metabolism and his intention of establishing nutrition investigations in his institute at Sao Paulo, Brazil, will, we believe, contribute greatly to the physiology of southern climates, and especially to our knowledge of the effect of sunlight on vital processes.

Dr. E. C. van Leersum, of Amsterdam, formerly professor in the University of Leyden, spent considerable time at the Nutrition Laboratory, making a careful study of its experimental techniques and administration in connection with the establishment of a national institute for nutrition in Holland.

Dr. Nils Stenström, from the laboratory of Professor J. E. Johansson of Stockholm, brought much of interest in regard to the physiology of work, especially swimming. He kindly cooperated in a series of body-surface temperature measurements with cold environment.

STAFF NOTES.

Under the present circumstances, the demand from the outside for staff members is very urgent, and the resignation of Professor H. Monmouth Smith, after seven years of very conscientious service, was received. With several years' experience in most successful teaching at Syracuse University prior to his coming to the Nutrition Laboratory, Dr. Smith goes to the Massachusetts Institute of Technology as professor of inorganic chemistry. His contributions to the accomplishments of this Laboratory can hardly be adequately recorded.

After a service beginning with the establishment of the Nutrition Laboratory, Mr. Warren E. Collins, mechanician and instrument maker of the staff, has resigned to enter private business. His superior construction of apparatus for our use has in large part created such a demand for apparatus designed in this Laboratory as to make its construction for hospitals and physicians a seemingly necessary private undertaking.

Foreign trip of Dr. W.R. Miles.—Prior to the war each year found some responsible member of the Laboratory investigatory staff visiting foreign institutes and laboratories in which work was being conducted in the same, or closely related, fields of research. Hardly any experience can be more stimulating to the scientific interest and zeal of a man than to come into personal contact with the workers of his own field. It is also noteworthy that while it is very profitable to associate with these men at scientific meetings and congresses, much more in net scientific results can be gained by visiting them in their own laboratories. Associations of this sort established relations of mutual understanding and appreciation and bear fruit in criticism prior to publication and to no little extent lead to cooperative undertakings.

Furthermore, by direct visits to the laboratories, advance information is obtained of research in progress, particularly at the present time, when, on account of the almost prohibitive cost of printing, many papers and larger reports of important and extensive studies are delayed in publication for a long time. Valuable details of laboratory equipment, which never appear in any way in publication, may likewise be discovered by going to the source. Aside from the more immediate personal and laboratory gains of such visits, it may reasonably be considered the duty of a man who is employed by an institution that has been founded for the "improvement of mankind" to make some effort to familiarize the world with the work of the laboratory which he represents and of the institution of which that laboratory is a part.

During the current year, Dr. Miles has visited laboratories in England, France, Belgium, Holland, Denmark, Sweden, and to some extent in Germany and Austria. He attended three scientific meetings: the British Psychological Association, London; British Physiological Association, Cambridge; and the Physiological Congress in Paris, giving papers at the latter two meetings. On June 16, in Amsterdam, Dr. Miles delivered an address on the work of the Nutrition Laboratory of the Carnegie Institution of Washington at the first public meeting in Holland regarding the establishment in that country of a national institute for nutrition.

Owing to conditions due to the war, it has been six years since the Nutrition Laboratory has been represented by a staff member in Europe. During this time a considerable number of changes have occurred in the personnel and organization of many foreign institutes and departments of physiological work, and it was deemed of great importance for the Laboratory to come into intimate touch with the conditions existing in present-day European science. Dr. Miles was everywhere greeted with the greatest cordiality, thus emphasizing that the interchange of such visits is bound to result in better international understandings.

The unique importance of nutritional conditions and of nutritional problems during the recent war, with the persistent shortage of food still bitterly experienced in certain parts of Europe, made it especially profitable for this Laboratory to secure some first-hand data on present nutritional conditions in those countries, especially the Central Powers, and to have a representative inspect to some extent the methods and work of certain relief organizations operating in the latter countries. With others of our staff, Dr. Miles was investigating the problem of undernutrition in this Laboratory during the war and could profitably observe the gigantic enforced experiment which has been taking place in Europe.

On account of the prevailing rate of money exchange, it has been extremely difficult for European scientists to purchase American

literature, and on all sides there is the urgent request that Americans will, especially at this time, be liberal in distributing papers and even larger monographs and books.

INVESTIGATIONS IN PROGRESS.

The neuro-muscular effect of alcoholic beverages containing 2.75 per cent alcohol by weight.—In the past only a little experimental work has been done with adults in which alcoholic beverages have been used so dilute as to contain but 2 or 3 per cent of alcohol by weight. Recent developments have indicated that it is precisely the effect of these beverages that is of practical importance. During November and December 1919, Dr. Miles conducted an intensive experiment on one subject, using as the standard dose 1 liter of 2.75 per cent alcohol and as a control dose 1 liter of water, after a very light lunch. A series of eight neuro-muscular measurements was repeated several times before and after taking the solution, and extensive data were collected by using different alcohol solutions. The data on the one subject show very consistent results. It was planned to use the same routine on a much larger group, but the work was interrupted by Dr. Miles's European trip.

Practice in static control.—A prolonged series of tests is being made by means of an apparatus for quantitatively measuring the static control in standing, with a view to accumulating normal records, ascertaining the amount of practice that is commonly required to reach approximate constancy, and the extent to which the score reflects the subject's general physical condition.

Determination of quantity of alcohol retained during inhalation.—Although the economic importance of the study of alcohol seems to be of less significance than when the alcohol program was first published, still the studies already begun warrant the continuation of the work, primarily on account of their great physiological interest, entirely aside from any other considerations. The study of the inhalation of alcohol with hens has been continued this year with reference to the determination of the quantity of alcohol actually retained. The general procedure has been to pass alcohol vapor through a chamber containing the animal. Determinations were made of the amount vaporized before the air entered the chamber and of the amount still remaining in the outcoming air; in this way the amount actually retained by the animal was indirectly obtained. In connection with the same study, an attempt was made to determine the respiratory exchange, particularly the respiratory quotient, by means of the Haldane chamber-method for animals. The studies were made by Dr. T. M. Carpenter with the cooperation of Miss Jane L. Finn.

Comparison of Haldane chamber-method for animals with gas-analysis method.—To insure the accuracy of the determination of the respiratory quotient in the study above mentioned, a comparison was made be-

tween the quotients obtained by the Haldane method for animals and those obtained by analyzing the outcoming air from the chamber. As the air entering the chamber was free from carbon dioxide and water, an analysis of the outcoming air gave the respiratory quotient directly. Such comparisons were made both by means of alcohol check-tests and with animals. These studies were carried out by Dr. T. M. Carpenter with the cooperation of Miss Jane L. Finn.

Determination of alcohol concentration in urine.—In connection with the study made by Professor Miles on the psychological effects of using beverages containing 2.75 per cent of alcohol by weight, the concentration of alcohol in the urines collected in half-hour periods was determined by Miss Jane L. Finn, assisted by Mr. Edward S. Mills.

Compilation of tables, factors, and formulas for computing respiratory exchange and biological transformations of energy.—The increasing use of metabolism studies in pure physiology and clinical work requires the utilization of various tables, factors, and formulas for computing the results. To have all of these available in one publication, a compilation has been made by Dr. Carpenter of the different tables used in such computations, together with the standards of metabolism and other formulas and factors commonly employed. The preparation of the tables was carried out mainly by Mr. William H. Leslie, assisted by Miss Clara E. Borden and Miss Mary D. Finn.

Metabolism as affected by cold environment.—The earlier work on a nude subject was supplemented by a few critical experiments on the same subject, though an extended series was impracticable. A respiration chamber for a medium-sized dog was provided with a special air-cooling device and a series of observations with low-temperature environments commenced.

Survey of skin temperature.—The simple apparatus for accurately determining skin temperature made possible a large number of observations upon a female nude subject. Dr. Nils Stenström, of Stockholm, kindly consented to serve as subject for a series of similar measurements to determine the effect of prolonged exposure to cold. Observations of the average skin temperature were made under the clothing on many staff members, and data for six subjects were secured after a night's rest in bed before rising. These observations were for the most part carried out by Miss Alice Johnson and Miss Marion L. Baker.

Study of the metabolism of oxen.—In continuance of the earlier work, two large oxen were given limited rations for several months and their gaseous metabolism studied in the respiration chamber at Durham, New Hampshire. As a result of the visit of Professor Ritzman to the Institute for Animal Nutrition, State College, Pennsylvania (Professor H. P. Armsby, Director), special arrangements were made to conduct a much more specialized study of metabolic processes during undernutrition, with complete analyses of hay, urine, and feces, as well as

measurements of the carbon-dioxide excretion. The data substantiate perfectly the results obtained in 1919 and supplement the previous study in many important phases. This work was mainly in the hands of Professor Ritzman and his assistant, Miss Helen Hilton. Special tests were made by Miss Alice Johnson, Miss Mary F. Hendry, and Miss Marion L. Baker, of the Laboratory staff, and a 24-hour experiment with an ox was easily made with the cooperation of all.

Respiration experiments on sheep.—Professor Ritzman has also used the apparatus at Durham, New Hampshire, most successfully for a number of experiments with groups of sheep. Several problems connected with pregnancy and subsequent growth are now being studied with these animals.

Calorific values of extra foods.—Unusual interest has been shown by physicians (and indeed the laity) in the calorimetric studies of extra foods, *i. e.*, foods taken outside of the regular meals. With special emphasis upon the more or less standardized drug-store and lunch-counter sandwiches, a considerable number were purchased, dried, and burned in the calorimetric bomb by Mrs. Cornelia Golay Benedict, assisted by Miss Mary D. Finn. The results of the work are now being prepared for publication.

Metabolism of snakes.—As representative of cold-blooded animals with their peculiar thermal regulations, large snakes were studied at the New York Zoological Park in continuation of the research work being carried on there by the Laboratory. The principal problem under investigation was the relative difference between the temperature of the the snake and of its environment. As in the past few years, the work has been entirely in the hands of Mr. E. L. Fox. As a further illuminating phase of the work, a 3-meter boa constrictor was brought to the Laboratory in Boston and intensively studied for about two weeks, during which time particular attention was given to the temperature in the cloaca and the skin temperature. The importance of the vaporization of water in the thermal regulation of the snake was also studied.

Metabolism of birds.—Making use of the superior collection of birds at the New York Zoological Park, we began the study of the metabolism of various birds, particularly those of unusual physical configuration. The work is progressing most satisfactorily with the assistance of Mr. E. L. Fox.

Conversion of carbohydrate into fat in the goose.—Our extended series of observations on this important physiological problem was supplemented by several months' work with a small compensation-calorimeter. The determination of the respiratory quotient under these peculiar conditions by means of several methods is still being intensively studied.

Metabolism of young girls.—The basal metabolism of normal girls from 12 to 17 years of age has thus far received but little attention. As a contribution to our extended investigation on the basal metabolism of humans of both sexes from birth to old age, a study of that period of girlhood was especially needed. Taking advantage of the now thoroughly established and well-tested group method of study, we made observations on nine groups of girls, usually 12 in each group, in the age-range of 12 to 17 years. To throw especial light upon the influence of maturity as evidenced by the appearance of menstruation, groups of girls of the same age, but differing in maturity, were studied. The whole research was made possible by the interest of Mrs. James J. Storrow, commissioner of the Massachusetts Council of Girl Scouts, and especially through the active cooperation of the numerous scout leaders, particularly Miss Alice Sandiford. The girls volunteered freely for these tests, and thereby have materially added to our knowledge of the physiology of normal girlhood. The results are ready for publication. The research was carried out with the cooperation of Miss Mary F. Hendry and Miss Marion L. Baker.

PUBLICATIONS.

The following publications have been issued during the present year:

(1) The caloric requirements of normal infants and children from birth to puberty. Fritz B. Talbot. Journ. Diseases of Children, 18, 229 (1919).

Using in large part the fundamental observations of the basal metabolism in studies made by the Nutrition Laboratory at the Massachusetts Boston Directory for Wet-Nurses and at the New England Home for Little Wanderers, Dr. Talbot has considered the relationship between the actual body-weight of children during the first year of life, the total caloric content of their food, the basal metabolism, the energy required for muscular activity and for growth, and the energy lost in the excreta. The hypothetical effects on growth of a decrease in the food-supply, diarrhea, fever, and excessive muscular activity are illustrated by a series of instructive charts.

(2) The basal metabolism of boys from 1 to 13 years of age. Francis G. Benedict. Proc. Nat. Acad. Sci., 6, 7 (1920).

From the measurements of basal metabolism of 60 boys under 10 kg. in weight and of 68 boys above 10 kg., a chart was prepared through which a line representing the general trend of metabolism was drawn. On the whole, the points for the boys weighing over 10 kg. were found to be more closely grouped about the line representing the general tendency than those for the boys under 10 kg. For the latter the average plus or minus deviation of predicted from actual was somewhat over 8 per cent. With the 68 values for boys above 10 kg. the predictions were considerably closer, the deviations being on an average 6.3 per cent. Using the basal metabolism of 136 men, Dr. J. Arthur Harris has derived by biometric analysis a multiple-prediction formula which may be used for predicting the 24-hour basal heat production of men as follows:

$$h = +66.4730 + 13.7516w + 5.0033s - 6.7550a.$$

In this formula h equals total heat production per 24 hours, w equals weight in kilograms, s equals stature in centimeters, and a age in years. Although the formula was established primarily for adults (but few of the subjects studied were below 20 years of age), it was found that the metabolism of the group of boys above 10 kg. could be predicted with an average deviation for individual predictions of plus or minus 56 calories, or 6.3 per cent. The prediction thus has an accuracy identical with that obtained by the curve plotted from actual measurements. This is of considerable practical importance as showing that the metabolism of males ranging from boys of 10 kg. up to full-grown adults, including the period of old age, may be predicted with this formula with an accuracy of not far from plus or minus 6 per cent.

(3) A respiration chamber for large domestic animals. F. G. Benedict, W. E. Collins, Mary F. Hendry, and Alice Johnson. Tech. Bull. No. 16, New Hampshire College of Agriculture (1920).

As a result of the development of a large respiration chamber for the study of the carbon-dioxide production of groups of men and women, another respiration chamber for use with large domestic animals was designed and constructed at the Nutrition Laboratory and finally installed at the New Hampshire Agricultural Experiment Station in Durham, New Hampshire. This article gives a description of the chamber and the results of a typical experiment with an ox. The chamber is sufficiently large to contain a very large ox. Uncontaminated outdoor air is driven into the chamber through the crevices around a special double door. The air is then withdrawn and forced into a wind-chest with two openings so adjusted in size that through one 90 per cent of the air is discharged directly into the laboratory and 10 per cent (or any desired proportion) can be collected, passed through suitable absorbers for carbon dioxide and water, and finally metered. The carbon dioxide absorbed is directly weighed. A movable platform permits graphic record of degree of repose of the animal. When weighed amounts of liquefied carbon dioxide are admitted, its quantitative recovery by the apparatus can be carefully checked. The apparatus has been in constant satisfactory use for two years. Its practicability for 24-hour tests has likewise been demonstrated and it has been used not only for oxen but for groups of sheep. The article contains several detailed diagrams and scale drawings.

(4) Notes on the use of the portable respiration apparatus. Francis G. Benedict. Boston Med. and Surg. Journ., 182, 243 (1920).

A number of studies have been made of certain factors connected with the rather extensive use of the portable respiration apparatus, and opportunity is taken in this paper to answer a number of questions that have been raised by investigators employing the apparatus. Particular attention is called to the necessity for scrupulous cleanliness with regard to the electric fan or hair-drier which moves the ventilating current of air. A substitute external method for ventilating the system is suggested. Finally, a warning is given against over-emphasis of the significance of deviations from the so-called normal, since in a recent study of 17 unpracticed, presumably normal, medical students it was found that two showed a metabolism of 14 or more per cent below so-called normal and one a metabolism of 11.5 per cent above so-called normal. A definite statement is made that there is no inflexible standard for normal metabolism for any given age, weight, height, and sex from which all normal individuals never vary.

(5) **A pursuit pendulum.** Walter R. Miles. Psychol. Rev., 27, 361 (1920).

A device is described for measuring the accuracy of the eye-hand pursuit coordination. A pendulum carrying a reservoir is arranged to swing over a sink or table, a small stream of water flowing from the lower extremity as the pendulum swings. The individual under test, seated before the sink, attempts to collect the water in a cup of limited diameter. A separate cup is used for each double swing of the pendulum and the volume of liquid collected in each cup is measured, and this measurement constitutes the score for efficiency. The release is by the fall of a small hammer visible to the subject. The device is its own chronometer and has no electrical features.

The catching of the liquid challenges the interest of most subjects. Results are presented for a group of 18 adults, practicing on 35 days. A fragment of alcohol data is introduced in the article to illustrate how the test may serve as a measure of neuro-muscular efficiency for one who has had considerable practice with the test.

DEPARTMENT OF TERRESTRIAL MAGNETISM.[1]

LOUIS A. BAUER, DIRECTOR.

GENERAL SUMMARY.

INTRODUCTORY REMARKS.

The difficulties encountered in the resumption of the Department's full program of pre-war work, mentioned in last year's annual report, have not abated, but, instead, have been increased by the continually rising costs of maintenance and operation, and by the imperative need of providing adequate compensation for those engaged in the advancement of science. Undoubtedly the effects of the war will make themselves felt for a long time to come, especially upon the successful prosecution of researches world-wide in their scope. Not only has it become imperative to curtail the Department's own work until the restoration of the pre-war equivalent of financial and human resources, but the same curtailment, in greater or less degree, has had to be made in the work of cooperating scientific organizations the world over. Depletion of staffs and diminution in purchasing capacity of available funds are serious problems facing those in charge of scientific establishments.

OCEAN MAGNETIC WORK.

It is a pleasure to be able to report that in regard to the ocean work the Department's program has been completely and successfully resumed, though, because of the greatly increased costs, somewhat at the expense of other lines of work, especially that of the magnetic survey of land areas. The present cruise (No. VI) of the *Carnegie* is proving to be one of the most successful, both in rate of progress and in work accomplished, of the vessel's cruises since her maiden voyage of 1909. The decision to convert the *Carnegie's* engine to operate on gasoline, instead of producer gas, in view of the peculiar difficulties encountered in attempting to make use of a non-magnetic power-plant, has proved to have been fortunate. Considerable more use of the engine in making and leaving ports and during calm weather has been possible than heretofore. According to the schedule as planned when the *Carnegie* left Washington on October 9, 1919, she was not expected to arrive at Lyttelton, New Zealand, until about December 11, 1920; instead, she was able to report her arrival at that port on October 20, 1920. At this rate of progress she may be expected, under favorable conditions, to conclude her cruise of 62,000 nautical miles at Washington about October 1, 1921, instead of the middle of November 1921.

Full share in the success of the present cruise must be given to the commander and his staff. The detailed statement of the vessel's operations, as prepared from Commander Ault's report, shows what

[1] Address, Thirty-sixth Street and Broad Branch Road, Washington, D. C.

has been accomplished during the current year by conscientious and zealous performance of duties assigned (see pp. 286-290). Reference to plate 1 will also be found of interest. By following on the map the ocean track marked VI, it will be seen how satisfactorily large gaps in our ocean work are being filled in and how much useful information respecting the changes in the Earth's magnetism is being secured by the frequent intersections of the present cruise with the previous ones.

Considering the difficulties of operating a ship under the present adverse conditions, especially one engaged in scientific work, the success of the *Carnegie* must be regarded as specially gratifying. It has again become possible to supply establishments engaged in the preparation of the magnetic charts used by mariners with the principal results of the *Carnegie's* observations within two or three months after they have been made. Tables of these results up to August 31, 1920, or up to the *Carnegie's* arrival at Fremantle, will be found summarized on pages 310–311.

The ports and dates of arrival will serve to indicate in a general way the portion of Cruise VI accomplished during the present year: Dakar, Senegal, November 24, 1919; Buenos Aires, January 19, 1920; Jamestown, St. Helena, March 27; Cape Town, April 24; Colombo, Ceylon, June 30; Fremantle, August 31, and Lyttelton, New Zealand, October 20. The length of the cruise from Washington to Lyttelton is about 34,000 nautical miles, which, added to the total length of the cruises, 1909–1918, 189,176 miles, gives an aggregate length of the *Carnegie's* cruises, 1909–1920, of about 223,176 nautical miles, or about 256,998 statute miles. Combined with the cruises of the first vessel, the chartered *Galilee*, 1905–1908, 63,834 nautical miles, gives a grand total of our ocean cruises, August 1905 to October 1920, 287,010 nautical miles, or 330,506 statute miles, which is somewhat over 13 times the Earth's circumference, and exceeds the mean distance of the Moon from the Earth by about 92,000 miles, or nearly three times the Earth's circumference. (For a summary of the Pacific Ocean work prepared for the First Pan-Pacific Scientific Congress at Honolulu, see p. 316.)

OCEAN ATMOSPHERIC-ELECTRIC WORK.

Investigations concerning the electrical state of the atmosphere over the oceans have been successfully resumed on the *Carnegie*. Daily observations are made of the potential-gradient, ionic content, conductivity, penetrating radiation, and radioactive content of the atmosphere. In addition, diurnal-variation observations consisting of hourly observations for 24 consecutive hours are made at least twice per month for as many of the elements as possible, usually potential-gradient, ionic content, and penetrating radiation. Meteorological observations are also made to accompany the foregoing in order to furnish data for a study of their interrelations with atmospheric-electric phenomena.

The Department, through its ocean work, is at present conducting the chief researches pertaining to the geographical distribution of the atmospheric-electric elements.

OCEAN MISCELLANEOUS WORK.

Besides the observations in terrestrial magnetism and atmospheric electricity, the following additional work has been carried out aboard the *Carnegie*, as far as the conditions and limited personnel permitted:

(a) *Atmospheric-refraction observations* by measuring the dip of the horizon with the view of collecting the necessary data for the gradual improvement of the refraction tables used by mariners in determining geographic positions of ship. Aside from the practical importance for safe navigation to have regions and causes of more or less abnormal atmospheric refraction indicated, such data are also of scientific interest for the perfection of the theory of atmospheric refraction. Nearly 4,000 observations in all parts of the ocean have been made aboard the *Galilee* and the *Carnegie* from 1907 to 1920. (Concerning studies and results of the accumulated data, see pp. 299 and 300.)

(b) *Meteorological observations* in cooperation with the United States Weather Bureau and in connection with the observations in atmospheric electricity are made daily. A large amount of meteorological data has been supplied to the Weather Bureau during the period 1905–1920. Special attention has also been paid to occurrences of thunder at sea and to its distances from land. Any other phenomena of interest, such as storms, polar lights, St. Elmo's fire, etc., are diligently recorded. Furthermore, *photographs of clouds* are being made in accordance with the suggestions of Professor W. J. Humphreys, of the United States Weather Bureau.

(c) *Geographic data* of importance pertaining to charted positions of islands or of coasts are obtained from time to time. Notable contributions of interest to the geographer and to the mariner have already been made, particularly on some of the special cruises, such as that of the circumnavigation of the Subantarctic regions by the *Carnegie* December 1915 to April 1916.

(d) *Ocean-current observations* have been made in the past as was found possible. During the present cruise (VI), special studies are being made in cooperation with the Department of Marine Biology with apparatus and according to directions furnished by Dr. Mayor.

(e) *Rock specimens* are being collected at ports of call in cooperation with the Geophysical Laboratory for Dr. Washington's investigations.

LAND MAGNETIC-SURVEY WORK AND SPECIAL EXPEDITIONS.

As has already been intimated, it has been necessary, because of the increased cost of field-work and lack of available personnel, to limit the land magnetic surveys even for areas over which data are urgently required for the completion of the magnetic charts of the globe. In

fact, it has been possible to have but one land party continuously in the field, namely, that under the charge of Observer Frederick Brown.

During the year Mr. Brown has been at work in Central Africa. He successfully completed magnetic-exploratory expeditions through Cameroon to Lake Tchad, French Equatorial Africa, as also through Angola and British Central Africa to Portuguese East Africa and Madagascar. Besides obtaining new magnetic data, he has been able to reoccupy some of our former stations in Africa, thereby securing data for determining the secular changes in the Earth's magnetism.

As heretofore, the *Carnegie* observers, in addition to the ocean magnetic work, have obtained valuable magnetic data at the vessel's ports of call.

Captain Roald Amundsen, with instruments loaned him by the Department, secured during his Arctic expedition a series of magnetic observations in 1918–1920 at his winter quarters and at about 40 points along the Siberian Coast. The original records of this work, which were to have been forwarded by way of Dickson Island, have unfortunately been lost on the coast of Siberia, but copies of essential parts have been received by way of Nome, Alaska. In accordance with Captain Amundsen's aerogram request, received in March 1920 through the United States Navy Department, the Department sent him additional equipment to Nome, where he arrived at the end of July, leaving for the Arctic about two weeks later.

Some magnetic data for Australia have been received from the Government Astronomer G. F. Dodwell of the Adelaide Observatory and Professor Kerr Grant; the observations were made in part with instruments loaned by the Department and in accordance with our methods. Also, some further magnetic data pertaining to the solar eclipse of May 29, 1919, have been received from various cooperating institutions.

The chief of the Magnetic Survey Division, Mr. Fleming, made an inspection trip to the *Carnegie* while at Buenos Aires, and after visiting various institutions in Brazil and Argentina, he inspected the progress of the magnetic observatory buildings being erected under Dr. Edmonds's direction. (For further details, see pp. 293–295.)

It may not be without interest to record here, for a summary of the land work, that during 1905 to 1920 the observers of the Department have made magnetic observations at about 4,000 stations in all parts of the Earth, at about 10 per cent of which observations were repeated at various intervals of years in order to determine the magnetic changes. The stations are, on the average, 75 miles apart and are distributed over 121 different countries in Africa, Asia, Australasia, Europe, North America, South America, Arctic and Antarctic regions, and islands of the Atlantic, Pacific, and Indian Oceans. Over 1,000,000 miles

have been traversed by the observers without loss of life, though some of the routes followed were both difficult and fraught with danger.

The Department has furthermore cooperated with five Arctic expeditions and one Antarctic expedition, supplying instruments and instructions, training observers, and reducing the observations whenever necessary.

Besides the magnetic data obtained, geographic positions have been determined which have been furnished to cartographers for preparation of maps of more or less unsurveyed regions. Information of interest to geographers and travelers, collected by the observers, has been furnished freely by various persons and organizations upon request.

OBSERVATORY WORK.

Watheroo Magnetic Observatory, Western Australia.—As stated in the annual report of last year, the continuous photographic registration of the manifold changes experienced in the Earth's magnetic field during the day and year was begun on January 1, 1919. Since then this important work has been uninterruptedly in progress; the results are proving of such value as to justify amply the choice of location, which, it may be of interest to note, is almost antipodal to Washington. The remarkably brilliant display of the aurora borealis witnessed at Washington and elsewhere on March 22, 1920, it was found had its counterpart at the Watheroo Observatory as the aurora australis. Mr. Edward Kidson assumed full charge of the observatory early in November 1919, after Mr. Wallis's departure for Washington. (For details of work accomplished and results obtained see pp. 295 and 318.) The erection of the structures required for the observational work in terrestrial electricity (atmospheric electricity and earth currents) has had to be deferred until 1921.

Huancayo Magnetic Observatory, Peru.—In spite of delays of various kinds and difficult conditions, excellent progress has been made in the erection of the various observatory buildings, under the immediate charge of Dr. H. M. W. Edmonds, assisted by Mr. Albert Smith as foreman-carpenter. The observatory site of about 25.5 acres has an elevation above sea-level approximately 11,000 feet and is about 125 miles east of Lima. It is hoped that observational work may be begun about the middle of 1921. (For details, see pp. 294 and 296.)

Washington, District of Columbia.—The required standardizations of magnetic instruments have been made from time to time in the Standardizing Magnetic Observatory (see p. 302). For an account of the atmospheric-electric work in the deck observatory, see p. 308.

Miscellaneous.—Matters relating to the structural and observational work at Watheroo and Huancayo, which received attention at Washington, are briefly stated on page 297.

RESEARCH WORK IN WASHINGTON.

TERRESTRIAL MAGNETISM.

The receipt of the requisite data for reducing to a common standard the magnetic results accumulated since the publication of Volumes II and III of the "Researches of the Department of Terrestrial Magnetism" will make it possible to complete early in 1921 the manuscript for Volume IV. That volume will contain the final results of the land-magnetic observations 1914–1919 and the ocean work 1917–1919, as also some preliminary results for 1920. About ten reports on special researches, covering the subjects of terrestrial magnetism, terrestrial electricity, atmospheric refraction, and related topics, will accompany the volume.

The discussion of the results obtained from the geophysical observations by the Department and cooperating magnetic observatories in connection with the famous solar eclipse of May 29, 1919, has proved of extreme interest from various standpoints. The magnetic results bear out the conclusions drawn from those of previous eclipses that appreciable changes in the magnetic elements occur during an eclipse of the Sun. These changes, while of subordinate magnitude, are generally of the same character as the oscillatory changes which the Earth's magnetic condition daily undergoes. In the case of the solar-diurnal magnetic variation, during the Earth's rotation, an eclipse of the Sun occurs daily, sunlight being cut off from one side of the Earth by the opposite side. In the case of the eclipse magnetic variation, it is the interposition of the Moon between the Sun and the Earth that momentarily withdraws from the Earth the Sun's radiations, in varying amount, over the region of visibility. Approximately it may be said that the ranges of the solar-diurnal variation and of the eclipse magnetic variation vary in accordance with the cross-section of the Sun and Moon, respectively. It is believed that the investigation of the eclipse magnetic phenomena will have an important bearing upon the complete determination of the causes of the magnetic changes which occur during both the solar day and the lunar day. (For further information, see p. 298 and abstract, pp. 317 and 318. See also pp. 307 and 319 regarding the eclipse electric results, as well as abstract, p. 315, concerning possible bearing of the eclipse meteorological observations upon the deflections of light observed by the British expeditions.)

The discussion of the results of the intercomparisons of magnetic standards, obtained by the observers of the Department in all regions of the Earth, forms the subject of a special report for Volume IV, referred to above. For assistance in the control of the magnetic standards at Washington, it is hoped that before long the sine galvanometer, referred to on page 281 of the 1919 annual report, will be available.

The study of the effect of dynamic deviations upon results from magnetic instruments mounted on supports subject to motions such as are encountered, for example, on board ship, has been facilitated with the aid of automatic records of the roll and pitching being made on the *Carnegie* (see p. 300).

The following persons have taken chief part in the investigational work in terrestrial magnetism: L. A. Bauer, W. J. Peters, J. A. Fleming, H. W. Fisk, C. R. Duvall, C. C. Ennis, and H. B. Hedrick. For further accounts of above work, see abstracts, pages 298 and 299.

MAGNETISM IN GENERAL.

The completion of the non-magnetic building, known as the Experiment Building, at the Department's site in Washington, enabled Dr. S. J. Barnett to repeat, under the desired favorable conditions, his important experiments on magnetization by rotation in accordance with the two previously used methods, that of electro-magnetic induction and that of the magnetometer, with improvements and some modifications (see particulars on pages 305–306). For views of the Experiment Building see plate opposite page 306.

Preparations have also been made for further experiments upon the converse effect—rotation by magnetization.

For progress concerning construction of sine galvanometer, see page 307.

Assistance was rendered Dr. Barnett in the work of the Division of Experimental Work by J. A. Fleming (in connection with construction of the Experimental Building and of apparatus), S. J. Mauchly (assistant chief), C. A. Kotterman (laboratory assistant), and Instrument-makers C. Huff and G. H. Jung.

TERRESTRIAL ELECTRICITY.

The Section of Terrestrial Electricity, under the immediate charge of Dr. S. J. Mauchly, has been continued as part of the work of the Division of Experimental Work. Details of the work of the section will be found on pages 307-309.

At the laboratory at Washington are being made the only continuous photographic registrations in the United States of the electric potential-gradient and the electric conductivity of the atmosphere. These photographic records, aside from their purely scientific value, have proved of practical interest in connection with studies of electric disturbances in the atmosphere affecting wireless transmission, and use of them has been, and is being, made in this connection by the Signal Corps and the Bureau of Standards (see p. 309).

The improvements in instrumental equipments and methods of observation have made it possible to secure definite results of the effects upon the electric condition of the atmosphere which accompany an eclipse of the Sun. The electric results obtained by the Depart-

ment's expedition at Lakin, Kansas, during the solar eclipse of June 8, 1918, summarized on pages 307 and 308 of the 1919 report, have been confirmed by the observations of the Department's expedition at Sobral, Brazil, during the solar eclipse of May 29, 1919. (For a fuller account, see pp. 319-320.)

Assistance in the investigational work was rendered by Messrs. A. Sterling, W. F. Wallis, and G. R. Wait.

STANDARDIZATION AND INSTRUMENT WORK.

The investigations and work under this head have been conducted in the Magnetic Survey Division, in charge of Mr. J. A. Fleming, to whose report on pages 301-305 reference may be made for details. Mr. Fleming's report relates the progress made in the construction and improvements of various instruments and apparatus required for the experimental and observational work of the Department.

The success achieved in the construction and use of magnetic instruments of the Department's design has resulted in a demand for similar instruments by foreign institutions to such an extent as to make it unfortunately impossible under present conditions to respond to all the requests received.

Further attention has been attracted, by various institutions at home and abroad, to the methods developed by the Department in the making of non-magnetic castings.

Assistance in the investigational work was rendered Mr. Fleming by Magneticians H. W. Fisk and W. F. Wallis and Instrument-makers C. Huff, G. H. Jung, W. F. Steiner, and J. G. Lorz.

MISCELLANEOUS ACTIVITIES.

Atmospheric refraction.—A joint investigation was made by the Director and Mr. Peters concerning the bearing of certain geophysical observations made during the solar eclipse of May 29, 1919, by the Department's expeditions at Sobral, Brazil, and Cape Palmas, Liberia, and by the Brazilian expedition at Sobral, upon the deflections of light observed by the British expeditions. Mr. Peters confined his special attention to the computation of differential terrestrial refraction as dependent upon zenith-distance of star and meteorological conditions. In this connection it was found that certain formulæ in Chauvenet's "Spherical and Practical Astronomy" required amplification (see p. 299).

The dip-of-horizon measures made on the present cruise (VI) of the *Carnegie* were tabulated and adjusted, under Mr. Peters's direction, and the summary of results from 1907 to 1920 was brought up to April 1920. (For further account, see pp. 299-300.)

Assistance was rendered by Drs. Slocum and Hedrick, as well as by Computers Duvall and Ennis.

Investigational work of Research Associate Slocum.—Dr. Frederick Slocum, appointed Research Associate in the Department for the period of June 16 to September 15, investigated the following matters (see pp. 299-301):

1. Rigorous methods of computation of terrestrial-refraction corrections.
2. Methods and observations for dip-of-horizon made on the *Carnegie* and relation of the results to temperature differences of air and water, length and height of waves, angle at which the vessel cuts the waves, barometric pressure, and geographic region.
3. Dynamic deviations, tilting error of compass, expression for acceleration of a table subject to a crank-and-piston motion, and equations of motion of a compass needle on a table subject to a simple harmonic motion.

Building work.—On page 283 reference has already been made to the building work at Washington (Experiment Building). (See also p. 305.)

International Section of Terrestrial Magnetism and Electricity.—A sufficient number of countries having formally signified their adhesion to the International Geodetic and Geophysical Union, as well as having made payment of their respective contributions, this section may now be regarded as definitely established. The duties devolving upon the Director as secretary of the International Section and director of its central bureau have received attention from time to time.

American Section of Terrestrial Magnetism and Electricity.—This section of the American Geophysical Union was definitely organized in April 1920, for the purpose of assisting in carrying out the purposes of the International Section of Terrestrial Magnetism and Electricity, in particular as regards the furtherance of investigational woık in the United States of national and international scope. The present officers are: Louis A. Bauer, chairman (also vice-chairman of the American Geophysical Union); W. F. G. Swann, vice-chairman; J. A. Fleming, secretary.

Lectures on the solar eclipse of May 29, 1919, and related phenomena were given at a number of universities by the Director, who had observed the total solar eclipse of May 29, 1919, under very favorable conditions, at Cape Palmas, Liberia, where totality lasted the exceptional length of 6 minutes 33 seconds. Papers on the results of the geophysical observations were also presented by him before various academies and societies.

National Research Council.—Various duties have been performed by Messrs. Barnett, Bauer, Fleming, Mauchly, and Peters as members of committees of the council.

DETAILS OF OBSERVATIONAL WORK.

OCEAN-SURVEY WORK.[1]

After sailing from Washington on October 9, 1919, the *Carnegie* proceeded down the Potomac to Chesapeake Bay, where the usual "swinging-ship" operations were carried out on October 11. The vessel then proceeded to Solomons Island, where simultaneous observations of the potential-gradient of atmospheric electricity were carried out on board and on shore, with the vessel's sails in the various positions occupied during observations at sea. Here the Director of the Department joined the vessel for a final inspection. Upon the completion of the atmospheric-electric work, the *Carnegie* sailed for Old Point Comfort, where the Director bade farewell to the party. Mr. J. A. Fleming, chief of the Magnetic Survey Division, and Dr. S. J. Mauchly, chief of the Section of Terrestrial Electricity, left the vessel to return to Washington after all matters in their respective charges had been arranged.

After a few days' delay at Old Point Comfort, during which a steward was signed on and seven seamen were replaced, the *Carnegie* finally sailed from Hampton Roads, bound for Dakar, Senegal, on October 19, 1919.

Soon after leaving Old Point Comfort the vessel encountered the usual Gulf-Stream weather, consisting of heavy winds from various quarters, accompanied by rain-squalls and wet weather. Similar weather continued all the way to Dakar, with only a few pleasant days intervening. Two heavy storms were encountered, but no damage was done to the vessel. Upon approach to the African coast, the usual northeast trade wind was replaced by winds from the southwest to southeast, making it necessary to keep well to the eastward in making the approach to Dakar. During the four days before arrival at Dakar heavy easterly winds, the harmattan, blew fine sand from the African desert and moisture forming about the dust-particles developed into a fog which obscured the Sun while below 10° to 15° of altitude. At the same time the horizon was nowhere more than one-half mile distant, which made navigation extremely uncertain and the approach to land particularly hazardous. Altitudes of the Sun were measured from a position as near the sea-surface as possible and were then corrected for an estimated distance of the horizon. In spite of these uncertain conditions, the landfall was made as expected, and after standing off and on for 36 hours the *Carnegie* entered the harbor of Dakar under her own power when the haze lifted for a few hours on November 22, 1919.

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[1] From Commander J. P. Ault's reports.

On account of the presence of bubonic plague in Dakar, the *Carnegie* remained in that port only long enough to take on water and supplies, sailing for Buenos Aires on November 26, 1919.

Fair winds for the first 3 days were followed by 10 days of calms and light variable winds, during which time it was necessary to operate the engine. After safely rounding Cape Palmas, Liberia, the southwest monsoon was encountered, and it continued to blow from December 9 to December 18 as the *Carnegie* sailed southeastward into the Gulf of Guinea. Two days later the vessel entered the region of the southeast trade wind, and for 11 days the daily run averaged from 125 to 188 nautical miles, with fine weather and under good sailing conditions.

After leaving the trade-wind region, about 10 days were spent in crossing the belt of calms, variable winds, and storms before the vessel entered the River Plate. On each of the two nights before reaching the river a heavy storm from the westward occurred, with heavy rain and strong and shifting wind. Landfall was made with the aid of star observations during lightning flashes of the receding storm as they illuminated the horizon. Buenos Aires was reached on January 19, 1920.

During the stay of 33 days at Buenos Aires the work and equipment of the vessel was inspected by Mr. Fleming for the Director, whose contemplated visit had to be abandoned because of pressing matters at Washington. (See p. 293, Special Expedition, concerning Mr. Fleming's inspections.)

Various repairs were also carried out and the different magnetic instruments were intercompared on shore. Through the efforts of the American ambassador, the Argentine Government, as during previous visits of the *Carnegie*, extended various courtesies and privileges to the vessel during her stay at Buenos Aires. These courtesies and the facilities afforded by the Argentine customs officials were very much appreciated. Two watch officers, 1 cook, the mechanic, 7 seamen, and the 2 messboys were replaced here. On February 21, 1920, the vessel left for St. Helena.

A week of moderate winds was followed by a heavy gale on February 28 as the vessel entered the region of the "roaring forties." For 48 hours the vessel ran before the storm at the rate of 10 knots with only the goose-winged lower topsail set. She scudded in the heavy cross-sea, shipping wave after wave from stem to stern. As the vessel proceeded southward, the cold and disagreeable weather gave warning of the presence of ice. On March 3 and 4 four large icebergs were passed.

Gough Island was sighted on March 8 and several very interesting hours were spent passing this lonely, uninhabited island of the South Atlantic. Large numbers of the wandering and sooty albatross were present around the island, indicating this as one of their homes. Several specimens were caught and examined.

The latitude as given for Gough Island seems to be in error by 3'.4, our observations giving 40° 15'.8 S., instead of 40° 19'.2 S., as shown on British Admiralty chart No. 2228, for Penguin Islet.

St. Helena was reached on March 27, after a remarkable trip of 35 days, during which the daily run averaged 151 miles. During the 7 days at St. Helena the Department's magnetic station at Longwood was reoccupied. Several trips over the island were taken by the party, during which the various places of historic interest were visited. After fresh water and supplies were taken on board, the *Carnegie* sailed for Cape Town on April 3.

After 3 days of sailing in the southeast trade-wind, the region of variable winds and calms was entered. *Considerable lightning accompanied by heavy thunder was noted during some of the heavy squalls encountered in the middle of the South Atlantic, far from land.* The region of the westerly winds and storms was reached on April 11. Tristan da Cunha Island was sighted on April 15.

The usual cycle of atmospheric-pressure changes, with their corresponding storms and changes in the direction of the wind for these regions, was experienced. With high pressure northerly winds blow, shifting to northwest and west as the pressure decreases. The more rapid the decrease, the stronger the wind blows. At the lowest pressure point the wind shifts to southwest and blows hard if the pressure increases rapidly, shifting to south and southeast as the pressure rises, finally jumping to northeast and north as the highest pressure-point is reached.

Cape Town Harbor was entered on April 24, after 21 days at sea, during which the high average of 152 miles per day was made. Here the usual intercomparison of instruments was made at the Department's former station near the Royal Observatory. Considerable repair work to the vessel was undertaken. The decks and outside of the vessel were recaulked, the two ranges were overhauled and rebuilt, and various repairs were made to the plumbing.

The people of Cape Town made the stay of the party very pleasant by their generous hospitality and by the many courtesies extended. The port authorities granted all privileges to the *Carnegie* during her stay, and various exemptions were made by the government officials in the matter of payment of towboat charges, customs dues, and immigration regulations. Opportunity is here taken to make grateful acknowledgment of these many courtesies.

On May 20 the *Carnegie* sailed for Colombo, this port having been substituted for Aden in the revised route instructions. During this trip four strong gales were encountered and the winds between in general were strong. The vessel spent 19 days in the region of the "westerlies," after which the southeast trade-wind was picked up, with a few hours of calm intervening. After one week in the southeast

trades, the southwest monsoon was encountered, and this wind continued until our arrival at Colombo. *The route extended up into the Arabian Sea in order to cross the Carnegie's 1911 track and to relocate the agonic line.* While crossing this line, 6 declination determinations were made in 25 hours with perhaps more than the usual accuracy, in spite of the gale which was blowing.

At midnight on June 26 the light on Minikoi Island was sighted as expected. Eastward of Minikoi the monsoon was very light, so that the *Carnegie* did not reach Colombo until the morning of June 30, after being hove to off the port all night. The distance covered from Cape Town to Colombo was 6,665 miles, giving a high average run of 163.4 miles for the trip of 40.8 days.

The trip from Cape Town was unusual in that declination observations were made daily in spite of the unfavorable weather conditions. Rain or precipitation of some kind occurred on 29 out of 40 days. On but 6 days were declination observations made only once, on 29 days they were made twice, on 3 days they were made three times, and on 1 day they were made four times, when relocating the agonic line. The chart errors in declination for the southern part of the Indian Ocean averaged over 1 degree, sometimes reaching 2.5 degrees. In the northern part they were less than 0.5 degree.

At Colombo an extended program of intercomparisons of instruments was carried out at the Department's station in the grounds of the Colombo Observatory. The use of the observatory was freely offered by the surveyor-general and by the director of the observatory, Mr. Bamford; the ready cooperation thus received and courtesies shown by the various officials greatly facilitated our work.

The vessel left Colombo on July 24, the course being set for a point somewhat southwest of Java and thence generally southward to about latitude 33° south and longitude 85° east. Thence the vessel followed a track generally to the east and arrived at Fremantle on August 31. For 9 days during this part of the cruise continuous calm was experienced and the auxiliary power had to be used for a distance of 800 miles to get through the belt. Declination observations were made at over 50 stations.

The complete program of intercomparisons of ship's instruments was carried out at Fremantle. The land instruments aboard the *Carnegie* were also compared with the standards at the Watheroo Magnetic Observatory of the Department.

Upon the completion of the work at Watheroo, the *Carnegie* left Fremantle October 1, and followed a course to the south of Australia, reaching latitude about 50° south and longitude about 140° east. Thence the course was shaped to the northeastward for Lyttelton, New Zealand, passing through Cook Strait between North Island and South Island. Lyttelton was reached October 20 and on October 21

the following cablegram was received from the *Carnegie:* "All are well. *Careful search has been made for Royal Company Islands without result.* Fifty-four magnetic stations." Standardization observations were made for determination of instrumental constants at the Magnetic Observatory in Christchurch and intercomparisons of standards with those of the observatory were also obtained.

Throughout the cruise of the year, even in bad weather and under disagreeable conditions, the regular program of observational work was carried out. Magnetic observations and atmospheric-electric observations were made in accordance with the prescribed programs, complete diurnal-variation series for three or more electric elements being obtained at least twice each month in addition to the daily forenoon observations. In this connection it is of interest to note that the special potential batteries which were provided for this cruise (see pp. 297 and 300 of annual report for 1919) have thus far proved entirely satisfactory and have shown no signs of deterioration. The roll-and-pitch recorder has been used throughout the cruise to obtain records of the ship's motion; owing, however, to the large amount of current required for its operation and the constant attention necessary, such records have been confined to periods of half an hour in the middle of the magnetic observations. Some highly interesting records have been obtained and furnish valuable data for studies on dynamic deviations aboard ship (see p. 300). Tables 1 and 2, pp. 310-311 contain summaries of the preliminary results of the ocean magnetic observations on the *Carnegie* for Cruise VI from Hampton Roads to Fremantle, October 1919 to September 1920.

As opportunity afforded observations were made also to detect *ocean currents* in accordance with the method originated by Dr. A. G. Mayor; *cloud photographs* were taken in accordance with suggestions from Professor W. J. Humphreys, of the United States Weather Bureau; and *rock specimens* were collected at ports of call for the studies of Dr. H. S. Washington of the Geophysical Laboratory.

The personnel of the *Carnegie* party is as follows: J. P. Ault, chief of section of ocean work, in command; H. F. Johnston, magnetician, second in command; Russell Pemberton, surgeon-observer; A. Thomson, H. R. Grummann, and R. R. Mills, observers; A. Erickson, first watch-officer; C. E. Layer, engineer; L. Larsen, second watch-officer; C. Strom, third watch-officer; 2 cooks; 1 mechanic; 8 seamen; 2 cabin boys; in all 23 men.

LAND-SURVEY WORK AND INSPECTION WORK.[1]

As already stated on page 279, owing to the greatly increased cost of field-work and the necessity of maintaining the *Carnegie* in full commission, the land-survey work had to be restricted during the year;

[1]From the report of the Chief of the Magnetic Survey Division, J. A. Fleming.

but it has been possible to make additional new observations in Africa, as well as to obtain valuable variation data at some of the Department's previous stations and at the ports of call of the *Carnegie*.

AFRICA.

Observer F. Brown continued the work which he began in Africa, March 1919. He reached Fort Lamy, near the head of Lake Tchad, French Equatorial Africa, on September 10, 1919, having secured repeat observations en route at Garoua, the Department's station of 1914, on the upper Benue River. At Fort Lamy observations were made at the Mission Tilho station, which had been previously occupied in 1917 by Observer H. E. Sawyer of the Department. On September 18, Mr. Brown left Fort Lamy by small boat for Lai, 250 miles up the Lagone River, his progress being necessarily very slow on account of the flooded conditions of the country at the time. Lai was reached on October 9, after a difficult journey through the swamps against a swollen current under very trying tropical conditions. The route followed next, for an estimated distance of 550 miles, lay overland southward to Goré, westward to Baibokoum, thence south to Carnot on the upper waters of the Sanga, a tributary of the Congo River. Throughout this region the native tribes were at times distinctly unfriendly, but no open hostility occurred. From Carnot, reached November 9, to Ouesso, a distance of about 340 miles, the journey was contined by canoe and small boat. Ouesso was reached on November 21. Turning westward at this point, Mr. Brown proceeded by small steamer up the Ngoko River to Ngoila, and then for 300 miles to Abong-Mbang. Abong-Mbang to Olama, a distance about 200 miles, was easily made by canoe down the Nyong River, the expedition arriving at Olamaon on December 23.

During May 2 to December 23, 1919, Mr. Brown had established 69 stations, 3 of which were repeat stations. At several of the principal points he observed at more than one station in order to make certain that conditions would be suitable for future reoccupations. The total distance traveled was approximately 3,600 miles, of which less than 700 was by rail and steamer. The remainder was made by canoe or by carriers, the observer walking a large part of the journey. The average distance between stations, not considering secondary or auxiliary stations in the same locality, is a little over 50 miles. The helpful cooperation of the government officials throughout the territory traversed contributed no little to the successful issue of Mr. Brown's expedition through Cameroon.

While awaiting steamer connections, Mr. Brown reoccupied his stations at Olama and Douala. He left Douala on January 24 for Benguella, Angola, to begin a trip through Angola across Africa by way of Elisabethville and the Zambezi to Portuguese East Africa.

En route to Benguella he made repeat observations at the Department's stations, Libreville and Cape Lopez in French Equatorial Africa, and at 3 stations in the Belgian Congo. In Angola he observed at 7 stations where observations had been made previously, and at Loanda he also secured intercomparison of instruments at the João Capello Magnetic and Meteorological Observatory.

Mr. Brown's route through Portuguese East Africa followed the railway eastward from Benguella to the railhead, repeat observations being secured en route at Huambo. From the railhead he continued by carrier, following the projected railway route from Benguella to Elisabethville by way of Cuanza, Moxico, Nana Candundo, Kalene Hill in Northern Rhodesia, and Ruwe in Belgian Congo, where he reoccupied Mr. Wise's station of 1914, to Chilongo on the railway. After occupying the Department's station at Kambove, he reached Elisabethville at the end of June. Important secular-variation data were obtained during June 30 to the middle of July at the Department's stations, Elisabethville, Broken Hill, and Victoria Falls. A new station was also established at Livingstone. Leaving Kafue on July 23, he proceeded by carriers, the Kafue River route being impracticable, to Feira, arriving there about the end of July. He traveled thence down the Zambezi River to Chinde and Beira, arriving at the latter point late in September. After reoccupying the Department's Stations in Portuguese East Africa, he proceeded to Madagascar, where he expected to make comparisons of instruments at the Tananarive Observatory and to secure observations at a number of field stations. From Madagascar he will take up work along the east coast of Africa, reoccupying as many previous stations as practicable.

The observers of the *Carnegie* made magnetic observations at Cape Town during the vessel's call there.

ASIA.

Captain Roald Amundsen, with instruments loaned him by the Department, secured during the winter of 1918–1919, a series of observations at "Maudhaven" (latitude 77° 33′ N and longitude 105° 40′), the winter quarters of his Arctic expedition. The observational records for this work were to have been forwarded by way of Port Dickson, but unfortunately they were lost on the coast of Siberia. On reaching Nome, Alaska, at the end of July 1920, Captain Amundsen forwarded copies of the essential parts of these records, as well as of observational records for the winter of 1919–1920 at his station in latitude 69° 52′ N. and longitude 167° 43′ E. During the two winters short expeditions to points along the coast were undertaken, so that observations were made at about 40 points in all. After a short stay at Nome, Captain Amundsen resumed his Arctic explorations.

Observations were made at the Department station by the observers of the *Carnegie* during her call at Colombo, Ceylon.

AUSTRALIA.

Since the 1919 report there have been received from Government Astronomer G. F. Dodwell, of the Adelaide Observatory, cahiers of magnetic observations made at 7 stations by the Geodetic and Magnetic Survey of South Australia in cooperation with the Department. The observations were made by Mr. Dodwell and Professor Kerr Grant at various dates, 1916–1918, with instruments supplied in part by the Department.

Absolute observations, as well as continuous photographic registrations, have been obtained throughout the year at the Watheroo Magnetic Observatory. (See p. 295).

During the visit of the *Carnegie* at Fremantle, observations were made there, and intercomparisons with the observatory instruments at Watheroo were obtained. On October 20, 1920, the *Carnegie* reached Lyttelton, New Zealand, and carried out a series of intercomparisons with the magnetic instruments of the Christchurch Observatory.

SOUTH AMERICA.

The only magnetic observations made in South America during the year were those by the *Carnegie* observers at Florida, Buenos Aires, January and February 1920, and occasional observations by Dr. Edmonds during the construction of the Huancayo Magnetic Observatory, Peru.

INSPECTION WORK IN SOUTH AMERICA.

During January to March Mr. Fleming, as the Director's representative, made an inspection trip to South America, visiting the *Carnegie* at Buenos Aires and the projected Huancayo Magnetic Observatory in Peru. En route to Buenos Aires he called at the National Observatory of Brazil, meeting there, in the absence of Dr. Morize, Director Ferraz, in charge of the forecast work, and Mr. Lemos, in charge of the magnetic work.

Mr. Fleming arrived at Buenos Aires on January 29. He found the *Carnegie* in first-class condition and that the work was progressing in a very satisfactory manner. The new coils for the marine moving-coil galvanometer were mounted in the galvanometer tubes and balanced with some difficulty. (These were replaced later by a specially constructed tube, made upon Mr. Fleming's return to the office and supplied the *Carnegie* at Colombo.) A new high-resistance coil was mounted in marine earth-inductor No. 3 for experimental tests with the string galvanometer; it was found, however, that the string galvanometer was not sufficiently sensitive, the resistance of the only sputtered fiber available being much too great. A method to produce sputtered fibers of sufficiently low resistance therefore had to be developed, and a new stock was supplied the *Carnegie* at Colombo, from which point experimental work is being continued.

Having completed the inspection of the *Carnegie* and tests of the marine earth-inductors, Mr. Fleming, in company with Mr. George O. Wiggin, director of the Meteorological Office of Argentina, visited the magnetic observatories of that organization at La Quiaca and Pilar, leaving Buenos Aires on February 10. The La Quiaca Observatory is at an elevation above sea-level of 3,422 meters, the surrounding country being, in general, plain but somewhat rolling. The general conditions are such that earth-current and atmospheric-electric work could be carried on, as well as magnetic, seismological, and meteorological work. There had been erected at the site two wooden non-magnetic buildings, which had been built in sections at Buenos Aires and were intended for the absolute and variation observations. Arrangements were being made for the installation of the piers on which the variation and absolute instruments were to be mounted. The instruments for the work at La Quiaca consisted of an Eschenhagen magnetograph, Kew-pattern magnetometer No. 175 previously used at Pilar, and a French dip-circle provided with dip-needles by Dover. It was hoped that the magnetic section of the observatory would be in operation by the end of the year.

The Pilar Observatory, in charge of Dr. F. H. Bigelow, was visited on February 21. Two magnetographs are in operation there, one of the Eschenhagen type and the other of the Edelmann type. The absolute instruments are a Kew-pattern magnetometer No. 138 and an earth-inductor by Toepfer & Son. The records obtained at the Orcadas Observatory of the Argentine Meteorological Office are kept for reduction and compilation at the Pilar Observatory. Up to the present time it has been impossible to carry out vertical-intensity observations at Orcadas, but it is hoped that in the near future arrangements can be made for such records.

It being impossible, because of the rainy season, to proceed overland through Bolivia to Peru, Mr. Fleming returned to Buenos Aires and proceeded thence to Valparaiso, taking the coast steamer to Callao, Peru, where he arrived on March 19. While en route he visited the Meteorological and Geophysical Institute at Santiago, Chile, the present director of which is Dr. Carlos Henriquez. At the present time, funds do not permit of any magnetic or atmospheric-electric observations being undertaken by this organization, although it has an excellent equipment of atmospheric-electric instruments and absolute magnetic instruments. While at Valparaiso, Chile, Mr. Fleming visited Dr. Walter Knoche, who had previously done some special atmospheric-electric work for the Department. Dr. Knoche referred particularly to the desirability of studying atmospheric-electric phenomena in the high ranges of the Andes.

At Callao, Dr. Edmonds met Mr. Fleming, and they proceeded together to Huancayo. It was found that, despite the unusually

difficult conditions, and particularly the long delay involved in the final transfer of the observatory site to the Department, good progress had been made in the construction work. (See p. 296). While at Lima, Messrs. Fleming and Edmonds, in company with Mr. W. Walter Smith, chargé d'affaires of the American embassy, had the privilege of calling upon President Leguia of Peru, and expressing to him the Department's grateful appreciation of the interest shown by His Excellency and the Peruvian Government in the projected observatory and of the various courtesies extended respecting free entry of equipment and materials.

Mr. Fleming left Callao for New Orleans on March 31, arriving there April 15 and reporting at the office in Washington on April 17.

OBSERVATORY WORK.

WATHEROO MAGNETIC OBSERVATORY.

Magnetician E. Kidson arrived at the observatory on November 7, 1919, and relieved Magnetician W. F. Wallis, who left for the office at Washington on November 17. As stated in last year's report, the photographic registrations for the magnetic elements were begun on January 1, 1919. The following summary of the observatory work during the year is taken from Mr. Kidson's report:

Towards the end of 1919 it was possible to begin the preliminary reduction of the magnetograph records for the year. During 1920 the magnetograph has been kept in continuous operation. Furthermore, there were made daily meteorological observations, weekly determinations of the absolute magnetic elements, weekly time observations and monthly scale-value determinations for the variation instruments. All preliminary computations and checking of the various observations and the preliminary tabulation of 60-minute scalings from the magnetograms have been kept up to date and the records sent to the office of the Department. It was also possible by June 1920 to reduce the observations accumulated during 1919, when the time of Messrs. Wallis and Parkinson was almost entirely consumed by construction work. The final reductions and compilations of the observatory-data are under way. The improvements made during the year were as follows:

(1) The well was deepened by 15 feet in order to increase the water-supply, which had fallen off very seriously in consequence of two exceptionally dry seasons. It is hoped that by strict economy in summer it may not be necessary in future to cart water to the observatory.

(2) A wire fence has been erected around the main reserve of the observatory and a smaller one around the observers' quarters, garden, and orchard.

(3) A small shed for use as a store-room was built 100 feet in the rear of the variation observatory.

(4) A hooded sulky was purchased and an extension was built to the stable for housing it.

(5) The one-quarter-chain fire-break around the site has been plowed over, as also a fire-break around a 15 by 25-chain area surrounding the observatory buildings.

(6) The furnishing of the observers' quarters was completed.

(7) An addition to the observers' quarters, in accordance with the detailed plan supplied by the office, to provide a separate apartment for the assistant observer, was partly completed.

During the *Carnegie's* call at Fremantle the land instruments on board were taken to Watheroo and complete intercomparisons with the observatory instruments were obtained.

Mr. W. C. Parkinson has been chief assistant throughout the year.

HUANCAYO MAGNETIC OBSERVATORY.

Despite untoward conditions and an unusually severe rainy season during October 1919 to March 1920, Dr. H. M. W. Edmonds, magnetician-in-charge, asssisted by Mr. Albert Smith as foreman-carpenter, made excellent progress on the buildings for the Huancayo Magnetic Observatory. Considerable delay was experienced in connection with the purchase of the observatory site; however, the final titles to the property were legally recorded December 31, 1919. A considerable part of this delay arose from the fact that the land was largely owned on the community plan, and it was necessary to acquire small parcels to make up the whole tract from some thirteen different owners. The site is about 320 meters wide from east to west, with a length north and south of 388 meters on the west and 265 meters on the east, the north boundary being somewhat irregular, conforming to the road and public threshing-areas. The total area of the site is 10.3 hectares (about 25.5 acres.)

As all building material must be delivered by pack mules over 9 miles of poor trail from Huancayo, the assembling of building materials on the site is one of the most difficult features of the work. Orders for the lumber to complete the bill of materials for all the buildings were placed in December 1919. Not until June 1920 could all the materials be delivered at the site. The absolute observatory was practically completed in March, except for the interior lining of wall-board. By the beginning of the rainy season in October 1920 the variation observatory and office and the observers' quarters were under roof and the work of interior finishing was progressing rapidly; it is hoped that the magnetic recording-instruments may be installed by June 1921.

During March 18 to March 31, Mr. Fleming, chief of the Magnetic Survey Division, was in Peru and inspected the work at the observatory (see p. 294). Because of the high freight rates and delivery charges from Huancayo to the site, it was found impossible to consider using sawdust as an insulating material for the magnetic observatory buildings; accordingly Dr. Edmonds's plan to use straw was adopted. Despite the unusually large diurnal variation in temperature at Huan-

cayo, it is hoped that the straw insulation in connection with the design of the variation-observatory walls, which include many dead-air spaces, will reduce the range within the magnetograph room so that it will be not much in excess of 0°.1 C. per day.

Every facility is being extended Dr. Edmonds by the Peruvian Government and the privilege of free entry of all materials and apparatus has been given.

MISCELLANEOUS OBSERVATORY WORK.

Additional observatory intercomparisons were obtained during March 1920 by Observer F. Brown at the João Capello Observatory at Loanda, Angola. This is a government observatory under the Portuguese Marine Department. At the time of Mr. Brown's visit the observatory was in charge of the commandant of the port. Arrangements were just being made to install self-recording magnetic instruments, and it was expected that in April 1920 a director would be sent from Lisbon with self-recording instruments to set up a complete magnetic observatory. It is also expected that Mr. Brown will secure intercomparisons with the instruments used by the Rev. P. Colin, S. J., at Tananarive, Madagascar. During the *Carnegie's* stay at Lyttelton, New Zealand, intercomparisons were made with the standards of the Christchurch Observatory.

The necessary general instructions for the observatory work have been prepared from time to time. Various materials and supplies have been ordered and forwarded for both the Watheroo and Huancayo magnetic observatories. A system of binding and filing magnetograms so that they will be kept flat has been devised. The work of final reductions of the data obtained at Watheroo during 1919 to 1920 was under way at the end of the year. The chief of the Magnetic Survey Division and Dr. S. J. Mauchly, chief of the Section of Terrestrial Electricity, made a special examination at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey on June 29, concerning the possible installation of instruments for atmospheric-electric and earth-current work. A special joint report upon the results of this examination was submitted to the Director, who, in conjunction with Dr. W. van Bemmelen, during his visit to Washington in June, had also investigated the possibilities of future cooperative work in terrestrial electricity with the Coast and Geodetic Survey.

For a brief account of Mr. Fleming's visits to magnetic observatories in Brazil and Argentina, see pages 293 and 295.

The work accomplished in terrestrial electricity at Washington is described on pages 283 and 307.

DETAILS OF INVESTIGATIONAL AND EXPERIMENTAL WORK.

DIVISION OF RESEARCH IN TERRESTRIAL MAGNETISM.

This division is under the immediate charge of the Director and is concerned primarily with investigations relating to the phenomena and causes of the Earth's magnetic field and its variations. Preparatory studies for an analysis of the terrestrial magnetic field as based upon the data accumulated by the Department and cooperating institutions are under way. It may be of interest to note in this connection that, for the major part of the Earth, it will be possible to undertake the solution of some of the principal outstanding questions with the aid of practically the Department's data alone. This is a fortunate fact, because, in consequence of the great war, the results of some of the national magnetic surveys made by official and other organizations will not be available for a long time to come.

Geophysical phenomena during solar eclipse of May 29, 1919.—A detailed investigation has been made concerning some of the geophysical phenomena revealed during the solar eclipse of May 29, 1919, and their possible bearing upon the physical deflection of light observed during the eclipse by the British expeditions to Sobral, Brazil, and the Island of Principe, West Coast of Africa. We have here a problem of joint interest to the geophysicist and to the astronomer. The question was raised and discussed in various issues of *Nature*, December 1919 to April 1920, by several British investigators, whether there might not be appreciable abnormal refraction effects in the Earth's atmosphere as caused by meteorological changes during totality, which might enter into the observed light deflections. The question and causes of abnormal terrestrial refraction effects are of special interest also to the Department in connection with the discussion of the dip-of-horizon measures being made on the *Carnegie*. Hence a joint investigation was undertaken by the Director and Mr. Peters, in charge of the discussion of the *Carnegie* atmospheric-refraction observations (see p. 299). The main meteorological data available are those made by the Department's expeditions to Sobral and Cape Palmas and the Brazilian expedition to Sobral. The investigation can not be closed until some additional data obtained by the British expeditions have been supplied. (See abstracts of preliminary papers on the subject, pp. 315-316.)

Magnetic results of eclipse observations, May 29, 1919.—The magnetic observations made at about 30 stations over the globe by the Department and cooperating institutions in connection with the solar eclipse of May 29, 1919, were reduced and discussed. The observations were made at nearly all stations in accordance with the Department's program of work. A first summary of results and conclusions appeared in *Terrestrial Magnetism and Atmospheric Electricity* for September 1920. A fuller account of the investigation forms a special

report in Volume IV, Researches of the Department of Terrestrial Magnetism (see p. 317). In that report the results of previous eclipse magnetic observations are also given.

In consequence of the Department's appeals for cooperative magnetic and allied observations during solar eclipses, valuable and extensive data are now available not only for the study of eclipse magnetic phenomena but also for other studies, as for example, the propagation of magnetic effects over the Earth. With the results accumulated since 1900 in all parts of the Earth, there would hardly seem any question now that the magnetic condition of the Earth is appreciably affected during a solar eclipse.

Miscellaneous investigations.—Various other investigations have been completed and the manuscripts have been prepared for the special reports in Volume IV, referred to above, namely: Design and Construction of Special Compass Variometers, by L. A. Bauer, J. A. Fleming, and W. J. Peters; Results of Comparisons of Magnetic Standards, 1915–1920, by L. A. Bauer and J. A. Fleming; Magnetic Potential and Field Components of Uniformly Magnetized Ellipsoids and Homœoids, by L. A. Bauer; Some Discussions of Ocean Magnetic Work, by L. A. Bauer and W. J. Peters.

Besides those whose names have already been mentioned, the following persons rendered assistance in the Division at various times: F. Slocum, while Research Associate during summer of 1920; C. R. Duvall, C. C. Ennis, and H. B. Hedrick, computers; H. D. Harradon, librarian-translator; Emma L. Tibbetts, stenographer-computer; Evelyn Morey, stenographer.

ADMINISTRATIVE DIVISION.[1]

Atmospheric refraction—This was a joint investigation with the Director on the effects produced by differential refraction in the Earth's atmosphere (see p. 298). In the course of the investigation it was found that differential refraction formulæ given in Chauvenet's "Spherical and Practical Astronomy," Volume II, page 456, are much more limited in their application than might be legitimately inferred from the test. Chief assistance in computation was rendered by Dr. Hedrick. The method used in the investigation and the conclusions reached were subsequently verified by Dr. Fredrick Slocum, while Research Associate (see p. 285).

Dip-of-horizon observations made on the present cruise (VI) of the *Carnegie* were tabulated, adjusted, and the summary of results from 1907 to 1920 was brought up to April 1920. Special investigations of the results for Cruise VI were made by Dr. Slocum, who plotted them in various curves to discover relations with the accompanying data. The relation to dimensions of waves in particular was investi-

[1]From Report of W. J. Peters, in charge.

gated as thoroughly as the data permitted. Since especial instructions had been issued for Cruise VI for obtaining data regarding the dimensions of waves, it was expected that the investigation might explain a large part of the discordance in results heretofore noted. A relation was found between the height of waves and the observed dip-of-horizon, but it will account for only a small part of the discrepancies. Dr. Slocum confirmed our earlier conclusions to the effect that the instruments at present in use at sea, while sufficient for navigational purposes, do not yield results of the precision required for investigating changes in the coefficient of refraction.

Dynamic deviations.—Automatic records of the rolling and pitching are being received from time to time with the usual observations from the *Carnegie*. The records were taken and have been preserved under difficult conditions of heat and moisture, but nevertheless they are very satisfactory. It is regretted that more were not obtainable, but power for running the gyrostat was not available daily, as had been hoped. With the assistance of the Magnetic Survey Division, spools and winding-machine have been provided to facilitate readings, scalings, etc. An examination of the records shows three important points in connection with dynamic deviations, viz:

(1) The period of rolling is not constant, but varies during the observation or experiment between comparatively wide limits. For example, the time of a double roll during declination observations on June 10, 1920, varies between 6 seconds and 12 seconds.

(2) The motions of rolling and pitching are so complex that in curves extending over intervals of 50 to 60 minutes there are comparatively few and sometimes no exact repetitions.

(3) Any estimation of the average amplitude of roll made without considering the frequency might be very misleading.

Investigation was begun by Dr. Slocum to examine how far these conditions would modify the formula for simple harmonic motion used, for example, by Bidlingmaier (Erdmagnetische See-Beobachtungen, I Teil, pp. 271–292). After examining the work already done, Dr. Slocum deduced formulæ for the deviations of a compass, subject to the condition that the point of support of the needle or card is moving in a plane with simple harmonic motion. He subsequently investigated the same problem for damped and forced oscillations. By confining the motion to a plane, it is expected that tilting deviations will be eliminated to a large extent, if not wholly.

A preliminary motion table has been planned with Mr. Fleming's help and constructed in the workshop, for experimental purposes in connection with Dr. Slocum's investigation. This table does not take the place of the more elaborate one proposed for reproducing the actual motion of the *Carnegie* from automatic records. Besides experimental purposes, the table would be useful in balancing the special compass variometers in case of need.

The preliminary equations already deduced in the consideration of *tilting deviations* were confirmed by Dr. Slocum and found to accord with those of Starling. Dr. Slocum found that the subject had already been discussed by Lord Kelvin (Math. and Phys. Papers, Vol. IV, pp. 464–469) to some extent, but for compasses only.

Since December 1, 1919, the highly important duties involved in the first auditing of the miscellaneous monthly disbursements by the various divisions and expeditions of the Department and in preparing the requisite financial statements and inventories for the Institution have been intrusted to Mr. M. B. Smith, as chief clerk and cashier. Since 1908 these duties had been faithfully performed by Mr. J. H. Millsaps, who resigned in order to accept a position of responsibility in Chicago.

A large part of the time of the Administrative Division is given to the routine work of accounts, miscellaneous correspondence and typewriting, filing of photographs, and miscellaneous checking. Until June the progress maps were plotted by Mr. Smith, with Mr. Ennis's assistance in ocean plotting. Subsequently, this work was all turned over to Mr. Ennis. In the revision of field cahiers Mr. Duvall has worked under the supervision of the Magnetic Survey Division. The Table of Magnetic Results and descriptions of stations for Volume IV were prepared in part by Miss Tibbetts with the help and advice of the Magnetic Survey Division.

The personnel of the division during the year has been as follows: W. J. Peters, chief; C. R. Duvall, expert computer; J. H. Millsaps, bookkeeper-cashier, resigned December 31, 1919; M. B. Smith, advanced from property clerk in the Magnetic Survey Division to position of bookkeeper-cashier December 1, 1919, and to position of chief clerk December 18, 1919; H. D. Harradon, to December 1, 1919, librarian-translator, on which date he was transferred to the Division of Research in Terrestrial Magnetism; Miss Elsie E. Johnson, assistant librarian and typewriter, resigned November 30, 1919; Miss Emma L. Tibbetts, transferred from the Division of Research in Terrestrial Magnetism to the Administrative Division as stenographer-computer, November 26, 1919; A. J. S. Dixon was transferred from the position of day watchman in the Magnetic Survey Division to that of messenger, under the direction of the chief clerk.

MAGNETIC SURVEY DIVISION.

Mr. J. A. Fleming has continued as chief of the Division, with Messrs. H. W. Fisk and J. P. Ault as chiefs respectively of the Sections of Land Work and of Ocean Work. During December 28, 1919, to April 17, 1920, Mr. Fleming was in the field on inspection work. Captain Ault has been on field duty in command of the *Carnegie* throughout the year.

The work at Washington has been concerned chiefly with the preparation of manuscript matter for Volume IV, "Researches of the Department of Terrestrial Magnetism," covering the period 1914 to 1919. By November 1920 the computations and manuscripts relating to the tabulations of land and ocean results, descriptions of stations, and instrumental constants were completed. There were also prepared for that volume special reports on investigations by members of the division staff. Among the most important of the results are those concerning the constants and corrections of magnetometers and dip-circles. They indicate the necessity of close control, such as is exercised by the Department. For magnetometers it is found that gradual changes in inertia of magnet and suspension stirrup take place during field-work and play an important part in the apparent variations with time of corrections on standard. Development by oxidation under field conditions of imperfections on the bearing portions of dip-circle needles cause large variations in the corrections on standard at different inclinations; these variations must be determined by careful examination of needle-differences on the mean from observations with two or more needles at numerous stations. It would seem, in general, advantageous to replace the dip-circle, or at least control it, wherever possible, by an earth-inductor. For most dip-circles, such control, to be really effective, is necessary at intervals of 3° to 5° within the range of inclination covered during field-work.

Comparisons with standard magnetometer No. 3 and standard earth-inductor No. 48 were made for magnetometer No. 16 and for dip-circle No. 242 during November 1919, after Observer A. Sterling's return from South America. A special series of declination observations was obtained at the Standardizing Magnetic Observatory at Washington during the annular eclipse of the Sun on November 22, 1919. Upon the request received by wireless in March from Captain Amundsen, a pair of intensity needles for the dip-circle supplied him was tested and forwarded to Nome, Alaska, where he arrived at the end of July 1920.

The magnetic observations were reduced which were made by Department observers during the total solar eclipse of May 29, 1919, at Sobral, Brazil, and Huayao, Peru. Considerable time had to be given by Messrs. Wallis and Keulegan to the study and reduction of the variometer results obtained at Sobral and Huayao, where temporary installations of magnetographs had been made.

All office matters relating to the magnetic-survey operations and observatory work received attention as required. Other miscellaneous work included detailed drawings for instruments and reports, photographing of instruments, classifying and filing of supplies and instruments, instruction of new observers in methods of magnetic observations and computations, etc.

To facilitate the time work and control of timepieces by Mr. J. J. Capello, property and shipping clerk, a wireless outfit to receive signals from the Arlington station was designed and constructed by Mr. Sterling and installed in the chronometer room.

Besides the special reports for Volume IV, mentioned on page 299, in which members of the division took part, the following additional reports were prepared: Results of examination of sites for magnetic observatories, compiled by J. A. Fleming; construction of non-magnetic experiment building, by J. A. Fleming; auxiliary tables to facilitate revisions of field magnetic observations, by H. W. Fisk; discussion of corrections on standard for dip-circle needles, by H. W. Fisk; discussion of magnetometer corrections on standards in declination and horizontal intensity, by J. A. Fleming. Others not elsewhere mentioned who have been assigned temporarily from time to time to the division and who have contributed to the work done were Messrs. D. M. Wise, J. L. Trisler, H. B. Hedrick, M. B. Smith, and A. J. S. Dixon.

INSTRUMENT WORK.[1]

The work in the instrument shop during the year may be roughly classified as follows: equipment, 30 per cent; experimental, 20 per cent; improvements and repairs of instruments and buildings, 43 per cent; miscellaneous and stock, 7 per cent.

The new construction included: sine galvanometer No. 1 for the absolute determination of horizontal intensity and special appliances required in determining the constants, non-magnetic heating arrangements and current-distributing arrangements for the Experiment Building, and an apparatus for producing harmonic motion in connection with the investigation of dynamic effects on instruments mounted aboard ship. Especial attention had to be given to the details of precise working of marble for the coil mountings of the sine galvanometer and to the providing of the strictly non-magnetic materials required for its construction.

The experimental work was concerned chiefly with the development of special apparatus for the experimental work under Dr. Barnett's direction and to the development of the marine earth-inductor and of galvanometers suitable for use with it at sea. The first attempts to make use of the string galvanometer on board with the earth-inductor were not successful, because the only fiber available had too great resistance. Pending the development of methods to produce sputtered quartz fibers of suitable resistance by Dr. Mauchly (see p. 309), improvements were made in the design of the moving-coil type of marine galvanometer previously used. Tube 19499 was reconstructed and new coil with special fiber-clamping arrangements provided, so as to

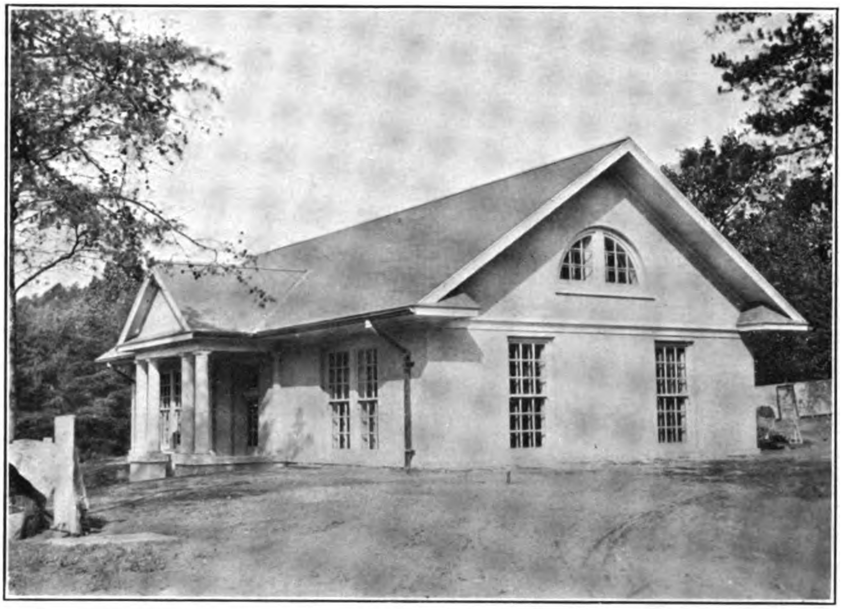
[1]From the report of the chief of the Magnetic Survey Division, under whose charge the instrument shop is placed.

reduce as much as possible the mass of the balancing-weights and consequent eccentricity of center of gravity of the moving-coil system as regards its line of suspension; a clamp was also added, so that the moving system might be clamped without distortion when the instrument was not in use and thus prevent the throwing out of balance caused by the vibrations of the engine when running. Some of the experimental work was in connection with the production of mirrors for laboratory use and with improvement of methods for optical work.

The improvements and repairs of instruments and buildings, as will be noted, engaged a large part of the time of the shop personnel. The most important part of this work included the overhauling and reconstruction of magnetometers 9, 12, 17, 19, and 21, and of dip-circle 223, all of which were in bad condition because of long and severe service in the field; minor repairs and reconstruction were affected on marine galvanometer tube 20697, collimator 2, magnetograph 5, conductivity apparatus 5, high-potential storage-battery, and miscellaneous magnetic, survey, and laboratory instruments and equipment. Building improvements were chiefly concerned with the Experiment Building; non-magnetic lead sash-weights, shades, screens, and switch-boards were designed and made for it. The machine-tool equipment was kept in order and repaired, and was increased by the addition of a turret attachment for one of the lathes. This attachment was needed particularly for the making of instrument screws of non-magnetic material which we have found it impossible to procure from outside manufacturers since the war.

As heretofore, all of the non-magnetic castings required in our work have been made in our own foundry under the direction of Mr. C. Huff. About 1,300 pounds of non-magnetic brass, copper, aluminum, and bronze castings, as well as about 1,300 pounds of lead sash-weights, were made during the year. The Department has communicated to the British Admiralty, upon request, the methods developed in its brass foundry for making non-magnetic castings, and instruction was given to representatives of the foundry department of the Bureau of Ordnance of the United States Navy in these methods.

The personnel of the instrument shop included Messrs. C. Huff, G. H. Jung, W. F. Steiner, instrument-makers, and J. G. Lorz, assistant instrument-maker. Mr. Huff has been engaged, in addition to his foundry work, chiefly on the design and construction of the apparatus required in the Division of Experimental Work. Mr. Jung has worked chiefly on the sine galvanometer, under Dr. Barnett's direction, and on the marine earth-inductor improvements. Messrs. Steiner and Lorz have done the bulk of the reconstruction work on magnetic instruments and on the redesign and improvement of the marine galvanometer and design and construction of the harmonic-motion apparatus.



Views of Non-Magnetic Experiment Building of Department of Terrestrial Magnetism at Washington.

BUILDING WORK AT WASHINGTON.

Various matters in connection with the final equipment of the non-magnetic Experiment Building, remaining undone last year, were completed. These included design and installation of non-magnetic shades and supports, installation of lead sash-weights, installation of screens, and miscellaneous matters. The steam and water pipes in the tunnel between the main laboratory and the experiment Building were covered with asbestos pipe-covering. The necessary extension of the switchboard in the main laboratory for the Experiment Building was completed. Two views of the Experiment Building are shown herewith.

The main laboratory, Standardizing Magnetic Observatory, and the two frame auxiliary observatories have been repainted and repairs were made as necessary. A new 60-volt storage-battery was assembled in the battery-room. Repairs were made on the macadamized roadways on the site, as they had been badly damaged by the unusually severe weather of the past winter. Some additional grading was done about the Experiment Building and site, drains for storm-water were provided, and a rough roadway to the east side of the site from the rear of the foundry was made.

Messrs. S. W. Malvin and T. S. Perry looked after the care of the grounds and did most of the improvement work about the site, while Mr. P. E. Brooke was caretaker and night watchman.

DIVISION OF EXPERIMENTAL WORK.[1]

Near the end of 1919, the prospects of occupying soon the Experiment Building, for work on the construction and equipment of which the division continues under great obligations to Mr. Fleming, became such that it was necessary to abandon for the time other work which had been started and to devote all the attention possible to the experiments on the relations between magnetization and rotation, and to the sine galvanometer, the superintendence of the construction of which devolved upon the chief of the division in December.

The Experiment Building was partially occupied in March 1920 and a magnetic survey (all elements) was made with the assistance of Messrs. Wallis and Sterling. The results of this survey showed that the desired uniformity of magnetic field within the building had been amply secured. The construction of piers and the mounting of the apparatus then began, and a great deal of progress has been made with the help of Mr. Kotterman and Mr. Huff, whose services became available for instrumental work a little later. (See views of Experiment Building herewith).

Experiments on magnetization by rotation.—These are in progress and are made by the two general methods described by the writer in the

[1]From the report of the chief of the division, S. J. Barnett.

Physical Review for 1915 and 1917, viz, the method of electro-magnetic induction and the magnetometer method:

(*a*) Method of electromagnetic induction. Much larger rotors and compensators, of pure iron, have been constructed to replace the rotors used in the earlier work, and a very large compensating frame has been constructed and mounted to neutralize the Earth's intensity as nearly as practicable in the regions they occupy. The winding is in two similar coils of parallel wires spaced to produce as nearly uniform a field as possible at the center. With this frame and the uniform field of the building it will be possible to get much more exact compensation than formerly, although fortunately this type of apparatus seems to give results largely independent of eddy currents, which the compensator is designed to eliminate. Provision is made for driving the rotors by electric motor at nearly uniform speeds, and it is hoped to get satisfactory results at higher speeds than formerly. It has not yet been possible to complete a special fluxmeter for this work, and it is going forward with an instrument of the ordinary type, borrowed from the Bureau of Standards.

(*b*) Magnetometer method. The apparatus for this method is largely that borrowed from the Ohio State University and is mounted much as in Columbus, Ohio, but with great improvements. Additional precautions have been taken against the presence of magnetic matter, against mechanical disturbances, and against the possibility of eddy-current effects on the magnetometer; many other improvements have also been made.

The magnetometer is now so mounted that the lower magnet can be placed in either the polar position of Gauss or a position resembling the equatorial position, used alone before. Few observations so far have been made with the magnetometer in the equatorial position. Many observations with iron and cobalt checked by copper to eliminate eddy-current effects, have been made in the polar position. There is already a marked improvement in the quality of the observations over those made earlier, but they have still to be greatly extended and further improved. Satisfactory observations have not yet been made on nickel. (See abstract, p. 313.)

Rotation by magnetization.—Since the report of last year, no further experiments have been made on the converse effect to magnetization by rotation, but such preparations for this work have been made as circumstances permitted. A special solenoid has been constructed to magnetize the body in a very uniform field, a compensating frame to neutralize the horizontal intensity of the Earth's field in the region occupied by the body has been constructed and mounted, a photographic device for recording the observations has been nearly completed, and other preparations have been made. It is hoped that observations will soon be well under way.

In one form of this investigation the magnetizing solenoid is wound on the core to be magnetized, and the other solenoid is used to neutralize the Earth's vertical intensity. Arrangements have been made to perform the experiment in this manner also, and a rotating commutator to furnish a "rectangular" alternating current of constant frequency has been constructed.

To furnish exceedingly constant speeds and frequencies for all these investigations, the system developed by Wenner has been adopted, with an improvement in the synchronism indicating device. The indicating commutators are so placed that the current in one of the two lamp lines is either a minimum or a maximum when the proper phase relation is established, and an ammeter in one of these lines indicates by its reading whether synchronism has been attained or is maintained. The commutator is placed on the D. C. motor or A. C. generator if frequencies are to be controlled; on the A. C. motor driven by the A. C. generator, itself operated by the D. C. motor, if the motor speeds are to be controlled.

Sine galvanometer.—Plans for the construction of this instrument were completed and much of the work of the instrument makers, Messrs. Jung and Huff, is now also complete. There remain the mirror and suspension, the scale, the supports for the magnetometer and the coils, and the winding of the coils. The circle has been investigated for errors of graduation and for eccentricity, and satisfactory magnetic tests have been made on the essential parts of the apparatus, so far as the construction has proceeded.

For papers published, see Abstracts, pages 313–315.

Throughout the observational work a great deal of assistance has been received from Mrs. Barnett.

Mr. Kotterman has performed the duties of laboratory assistant and has been engaged in work on instruments, photographic work, and clerical work.

SECTION OF TERRESTRIAL ELECTRICITY.[1]

The principal activities during the year under review have been as follows:

(1) *Reduction of eclipse atmospheric-electric observations.*—The atmospheric-electric data secured during the total solar eclipse of May 29, 1919, by the Department's expedition to Sobral, Brazil, were reduced and studied in detail. A preliminary report thereon was presented before the meeting of the American Physical Society at Washington, April 23, 1920 (see abstract, p. 320). A more detailed report on the results for this eclipse, together with a summary and discussion of the results of similar observations during solar eclipses from 1887 to 1919, inclusive, was given before the Philosophical Society of Washington on October 9, 1920. The full report and summary will appear in Volume IV of the "Researches of the Department of Terrestrial Magnetism."

(2) *Reduction of ocean atmospheric-electric observations.*—Owing to the interruptions in the Department's work occasioned by the war, no detailed publication of the atmospheric-electric observations made

[1]From the report of the chief of the section, S. J. Mauchly.

aboard the *Carnegie* has been made since the appearance of Volume III, "Researches of the Department of Terrestrial Magnetism." A supplementary report for that part of Cruise IV not covered in Volume III (May 17, 1916, to March 2, 1917) was published in the Director's annual report for 1917, p. 281. In view, however, of the fact that this supplementary report was based upon unchecked computations, and also because of the desirability of including complete detailed publication in the successive volumes of "Researches of the Department of Terrestrial Magnetism," it was deemed desirable to prepare such detailed data for all the atmospheric-electric observations made aboard the *Carnegie* subsequent to the publication of Volume III. Accordingly, a careful study has been made of all observational data corresponding to the period beginning with May 17, 1916, when the vessel left Lyttelton after the completion of her subantarctic cruise, and ending with the arrival at Washington, D. C., on June 10, 1918, at the completion of Cruise V.

Especial attention has been directed to the diurnal-variation observations which have been made aboard the vessel. In order to secure as large an amount of data as possible for this work, all available material from Cruises IV and V has been utilized, and it is believed that in the forthcoming report it will be possible to contribute some important conclusions relative to the average diurnal-variation of several atmospheric-electric elements over the Pacific Ocean.

On page 422 of Volume III it is stated that "as yet no detailed analysis of the observations has been made with a view to determining the interrelations between the atmospheric-electric quantities and latitude, temperature, humidity, and atmospheric pressure." Since practically all of the electric-diurnal variation observations were accompanied by simultaneous meteorological observations, it seemed worth while to carry out also a reduction of these observations for determining, so far as possible, what evidence is available concerning the mutual relations between the respective atmospheric-electric and meteorological elements at sea.

(3) *Observatory work at Washington.*—The atmospheric-electric observatory on the deck of the laboratory at Washington was continued in operation throughout the year. As in the preceding year, continuous photographic records of the electrical conductivity of the atmosphere and of the potential-gradient have been obtained, except for occasional days or parts of days when repairs were under way, or when the obtaining of good records was prevented by meteorological conditions or by insects. Practically complete records of the conductivity were obtained for more than 85 per cent of all days during the year, with partial records for most of the remaining days. A similar statement applies with regard to the potential-gradient, except that the complete records in this case were obtained for 95 per cent of all days.

(4) *Ocean atmospheric-electric observations.*—The requisite examinations were made of the data being obtained on the *Carnegie* and additional instructions for the ocean work (see p. 279) were prepared as found necessary.

(5) *Miscellaneous.*—In order to supply conducting quartz fibers for the string electroscopes in use both at the laboratory and aboard the *Carnegie*, and especially to secure such fibers of conductivity suitable for use with the string galvanometer aboard the *Carnegie*, the matter of production of conducting fibers by the method of cathodic sputtering has received careful attention in the laboratory at Washington. An improved form of sputtering tube was devised and considerable study given to the technique and to various theoretical matters involved in the work. The production of these fibers in our laboratory was begun only after it was found to be impossible to secure suitable fibers from commercial sources. Liquid air used in connection with the sputtering of quartz fibers was kindly supplied by the Bureau of Standards.

At the request of the Director, the feasibility of installing equipment for earth-current and atmospheric-electric observations at the Cheltenham Observatory of the Coast and Geodetic Survey was investigated by Messrs. Fleming and Mauchly. A visit was made to Cheltenham to study the local conditions and a joint report was submitted concerning the entire subject.

The Department has cooperated to a limited extent with the Radio Laboratory of the Bureau of Standards in a study of the "swinging" of radio signals on short wave-lengths. The extent of this cooperation thus far has consisted in attendance by Messrs. Mauchly and Sterling at two conferences for the discussion of problems and plans, and in placing the Department's atmospheric-electric records at the disposal of the Bureau for inspection and study. There is a possibility that this cooperation may yield information of value in connection with the study of the ionization of the atmosphere.

In addition to his regular duties, the chief of the section, acting under instructions from the Director, assumed charge of the instrument shop, buildings, and grounds, for the first four months of 1920, during the absence of Mr. Fleming on official business in South America.

For publication work, see abstracts, pages 320-321.

Much valuable assistance was rendered for various periods by the following members of the Department: G. R. Wait, assistant physicist; Allen Sterling, observer; and C. M. Little, assistant observer. Mr. W. F. Wallis, of the Magnetic Survey Division, also assisted at various times.

ABSTRACTS OF PUBLICATIONS AND INVESTIGATIONS.

Preliminary results of ocean magnetic observations on the *Carnegie* from Washington, D. C., to Dakar, Africa, thence to Buenos Aires, South America, October 1919 to January 1920. J. P. Ault. Terr. Mag., vol. 25, 9–13 (Mar. 1920).

Preliminary results of ocean magnetic observations on the *Carnegie* from Buenos Aires, South America, to St. Helena, February and March 1920. J. P. Ault. Terr. Mag., vol. 25, 49–52 (June 1920).

Preliminary results of ocean magnetic observations on the *Carnegie* from St. Helena to Cape Town, thence to Colombo, Ceylon, April to June 1920. J. P. Ault. Terr. Mag., vol. 25 (September 1920).

These three papers give the preliminary results of the magnetic observations on the *Carnegie* during the present cruise (No. VI) from Washington to Colombo, Ceylon, October 1919 to June 1920. Notes on the various passages are also given.

Table 1 will serve to show the magnitudes of the chart differences as determined from a comparison of the *Carnegie* observed values of the magnetic elements with values scaled from the most recent magnetic charts: For *declination*, U. S. Hydrographic Office No. 2406 for 1920 and British Admiralty No. 3775 for 1917; for *inclination*, U. S. Hydrographic Office No. 1700 for 1920; and for *horizontal intensity*, U. S. Hydrographic Office No. 1701 for 1920. The new material for these charts was supplied almost entirely by the Department of Terrestrial Magnetism.

In order to explain the significance of the letters *E*, *W*, *N*, *S* as affecting the application of the chart differences, it may be stated that *E* and *N* have been treated as being plus, *W* and *S* as minus, the chart difference being equal to the *Carnegie* value minus the chart value. The horizontal intensity is always regarded as positive, and the signs, plus and minus, have their usual significance.

TABLE 1.—*Range in chart differences.*

Cruise VI.	Date.	Declination.		Inclination.	Horizontal intensity.[1]
	1919–20.	British.	U. S.	U. S.	U. S.
Washington-Dakar	Oct. 14–Nov. 22	0°.7 W to 0°.6 E	0°.9 W to 0°.5 E	0°.8 N to 1°.2 S	+4 to −2
Dakar-Buenos Aires	Nov. 27–Jan. 18	1.0 W to 1.4 E	1.1 W to 1.4 E	0.3 S to 3.3 S	+4 to −4
Buenos Aires-St. Helena	Feb. 24–Mar. 26	1.8 W to 1.0 E	2.0 W to 0.8 E	0.0 to 2.1 S	+3 to −7
St. Helena-Cape Town	Apr. 4–Apr. 23	1.6 W to 1.3 E	1.4 W to 1.8 E	0.5 S to 1.5 S	+1 to −7
Cape Town-Colombo	May 21–Jun. 29	1.8 W to 2.3 E	1.9 W to 2.5 E	3.3 N to 1.8 S	+6 to −8
Colombo-Fremantle	Jul. 24–Aug. 30	1.8 W to 0.5 E	1.9 W to 0.3 E	0.2 N to 1.6 S	+5 to −6

[1]Units of third decimal C. G. S.

Preliminary average annual changes of the magnetic elements in the Atlantic Ocean, 1909 to 1920. J. P. Ault.

The annual-change values given in table 2 were obtained by utilizing the results of observations made near the different points of intersection of the *Carnegie's* several cruises from 1909 to 1920. As it is practically impossible to repeat observations at precisely the same spot, all the values used were compared with the values as shown on the U. S. Hydrographic Office magnetic charts for 1920. The difference in the chart corrections for two groups thus obtained, divided by the time-interval in years, was taken as the average annual change for the mean position of the two groups under consideration. This method is similar to the method of straight-line interpolation as outlined

on page 431, Volume III, Researches of the Department of Terrestrial Magnetism. Time was not available for the making of a least-square adjustment of the various values.

TABLE 2.—*Preliminary average annual changes for the Atlantic Ocean.*

Lat.	Long. east of Gr.	Approximate dates showing time-intervals.	Average annual change.			Number of values utilized.		Annual change in declination			
								Chart values.		Chart diff's.	
			D	I	H[1]	D	I and H	U. S.	B. A.	U. S.	B. A.
°	°		′	′				′	′	′	′
38.8 N	308.6	1910.5–1914.5	3 W	...	...	4 and 4	...	2 W	4 W	1 W	1 E
39.2 N	307.7	1914.5–1919.8	4 W	...	...	4 and 4	...	2 W	4 W	2 W	0
38.2 N	308.8	1910.5–1919.8	3 W	...	...	4 and 4	...	2 W	4 W	1 W	1 E
39.0 N	308.2	1910.5–1914.5	...	7 S	+ 7	...	4 and 3	...	...	...	...
39.5 N	307.3	1914.5–1919.8	...	2 N	− 6	...	3 and 3	...	...	...	...
38.3 N	307.5	1910.5–1919.8	...	2 S	− 1	...	4 and 3	...	...	...	...
38.4 N	289.6	1915.2–1919.8	11 W	...	...	2 and 3	...	5 W	6 W	6 W	5 W
38.3 N	290.9	1910.3–1919.8	8 W	...	...	7 and 3	...	5 W	6 W	3 W	2 W
37.9 N	291.1	1913.9–1919.8	10 W	...	...	5 and 3	...	5 W	6 W	5 W	4 W
38.5 N	290.3	1910.3–1915.2	...	8 N	−10	...	7 and 2	...	...	...	...
38.2 N	289.0	1915.2–1919.8	...	4 S	− 6	...	2 and 2	...	...	...	...
38.1 N	291.1	1910.3–1919.8	...	2 N	− 8	...	7 and 2	...	...	...	...
37.7 N	292.0	1910.3–1913.9	...	2 N	− 7	...	7 and 4	...	...	...	...
37.4 N	290.6	1913.9–1919.8	...	2 N	−10	...	4 and 2	...	...	...	...
37.9 N	297.8	1910.5–1919.8	...	1 N	− 7	...	2 and 3	...	...	...	...
38.5 N	320.5	1913.6–1919.8	...	1 S	− 2	...	2 and 2	...	...	...	...
38.5 N	320.4	1913.6–1919.8	1 W	...	...	2 and 3	...	2 E	1 E	3 W	2 W
36.7 N	331.1	1913.9–1919.9	4 E	...	...	3 and 3	...	3 E	3 E	1 E	1 E
36.3 N	330.5	1913.9–1919.9	...	4 S	+ 3	...	2 and 3	...	...	...	...
28.8 N	340.6	1909.9–1919.9	...	6 S	+ 2	...	2 and 2	...	...	...	...
28.8 N	340.4	1909.9–1919.9	4 E	...	...	4 and 4	...	3 E	4 E	1 E	0
9.3 S	348.3	1913.6–1920.0	...	20 S	− 3	...	3 and 3	...	...	...	...
9.8 S	348.3	1913.6–1920.0	4 W	...	...	3 and 3	...	2 E	2 E	6 W	6 W
14.2 S	343.8	1913.3–1920.0	4 W	...	...	2 and 3	...	1 E	1 E	5 W	5 W
14.3 S	343.5	1913.3–1920.0	...	15 S	− 5	...	2 and 2	...	...	...	...
15.9 S	354.3	1913.4–1920.2	0	15 S	− 5	At St. Helena.		...	...	...	...
16.1 S	354.7	1913.4–1920.2	...	14 S	− 6	...	3 and 3	...	...	...	...
16.5 S	354.5	1913.4–1920.2	2 E	...	...	9 and 8	...	3 E	3 E	1 W	1 W
26.1 S	6.3	1913.2–1920.2	...	14 S	− 7	...	2 and 2	...	...	...	...
26.5 S	6.3	1913.2–1920.2	5 E	...	...	2 and 2	...	7 E	4 E	2 W	1 E
27.4 S	330.1	1913.4–1920.0	...	11 S	− 6	...	3 and 2	...	...	...	...
27.8 S	330.2	1913.4–1920.0	10 W	...	...	2 and 2	...	3 W	4 W	7 W	6 W
31.6 S	343.2	1913.4–1920.3	...	10 S	− 5	...	3 and 3	...	...	...	...
32.0 S	344.9	1913.4–1920.3	8 W	...	...	3 and 9	...	3 E	2 E	11 W	10 W
33.9 S	18.5	1911.3–1920.4	11 E	9 S	−11	At Cape Town		...	...	...	...
36.0 S	304.4	1911.0–1917.6	9 W	...	...	10 and 13	...	9 W	9 W	0	0
35.8 S	305.6	1911.0–1920.1	10 W	...	...	10 and 7	...	9 W	9 W	1 W	1 W
36.4 S	305.2	1917.6–1920.1	11 W	...	...	13 and 7	...	9 W	9 W	2 W	2 W
36.9 S	7.4	1913.2–1920.3	...	14 S	−14	...	4 and 2	...	...	...	...
37.9 S	7.7	1913.2–1920.3	2 E	...	...	2 and 2	...	7 E	6 E	5 W	4 W
37.3 S	10.9	1911.2–1920.3	...	16 S	−14	...	2 and 3	...	...	...	...
37.4 S	10.8	1911.2–1920.3	4 E	...	...	2 and 4	...	8 E	8 E	4 W	4 W
39.2 S	29.1	1911.3–1920.4	...	3 S	− 8	...	2 and 3	...	...	...	...
39.4 S	28.8	1911.3–1920.4	12 E	...	...	3 and 4	...	9 E	11 E	3 E	1 E
41.4 S	347.0	1911.2–1920.2	...	7 S	− 9	...	2 and 2	...	...	...	...

[1]Units of fourth decimal C. G. S.

Particular attention is called to the steep gradient between the lines of equal annual change in the South Atlantic Ocean, especially in the vicinity of Cape of Good Hope. The variation with time in the annual change of the declination for this locality has been very large, as evidenced by the results of the shore observations made at Cape Town. The annual change was 3′ E in 1911, whereas in 1920 it was 11′ E.

The last four columns show the corresponding annual changes for declination as given on the latest magnetic charts: British Admiralty for 1917 and U. S. Hydrographic Office for 1920, together with the corrections to be applied to these chart values to obtain the *Carnegie* values. The second and third values from the bottom of the table are in the Indian Ocean, but are included here to show the distribution in the vicinity of Cape of Good Hope. The values are arranged according to latitude, but where several intersections occur near the same locality, the values for these intersections are arranged according to the dates in order to show up any progressive change or variation with years. The results are subject to slight changes when the final reductions are made at the end of the present cruise of the *Carnegie*.

The annual changes for declination and inclination are referred to the north-seeking end of the magnetic needle. Thus 6′ W signifies that the north-seeking end of the compass moved to the west at the average annual rate of 6′ during the period shown in the third column of the table; 1′ N means that the north-seeking end of the dip-needle moved downward at the average annual rate of 1′ during the period in the third column; horizontal intensity is always considered positive, and the signs, plus and minus, have their usual significance.

A double solenoid for the production of uniform magnetic fields. S. J. Barnett. Philos. Mag., vol. 40, pp. 519–520 (1920).

Probably the best way in which a single-layer coil can be constructed with great precision is by winding uniform round wire in a spiral groove accurately cut in a circular cylinder, as first suggested by Viriamu Jones and as exemplified in the work of the National Physical Laboratory. If the cylinder is conducting, and long, as in the case of a solenoid, the effect of the leads may be practically eliminated, as they often are, by connecting one end of the coil to the cylinder and using the other end as one terminal, but such a coil can not be used satisfactorily with alternating currents.

In order to produce fields of moderate intensity in ordinary circumstances, a solenoid must have at least several layers. Such a coil may be constructed with precision, as Bestelmeyer[1] has pointed out, by winding one layer as described above, and with pitch considerably less than twice the diameter of the wire, winding a second layer in the same direction in the depressions between the first, and so on. A serious defect of this arrangment, however, is due to the long conductors necessary to connect the far end of each coil with the near end of the next, which may interfere greatly with the direction and uniformity of the field due to the spiral windings.

All the advantages of precise winding may be obtained, and at the same time the (small) effect of spirality on the uniformity of the field may be largely eliminated and the trouble due to connectors and leads avoided, as follows: Two solenoids are constructed with the same pitch and number of layers, and with practically the same length, but with somewhat different diameters, so that one may be placed inside the other. One coil is wound in left-handed spirals, the other in right-handed spirals, and the two are mounted coaxially

[1] Phys. Zeit. 1911, p. 1107.

and concentrically. The construction necessitates that the successive layers in each solenoid start from points 180 degrees apart. When each coil has two or more layers it is probably best to wind all layers of one coil with the same integral number of turns, and all layers of the other coil with this same number of turns plus or minus one-half turn. It is then clearly possible to join successive layers of the two solenoids systematically in series by very short connectors at the ends, in such a way that the current goes alternately up a layer of one solenoid and down a layer of the other, and that the small effects of each pair of short connectors are practically canceled near the center of the field. Difficulties are encountered in making the windings precise close to the ends, but slight irregularities there are of little consequence.

In a large double solenoid constructed in the laboratory of the Department of Terrestrial Magnetism the coils are wound on tubes of bakelite-dilecto, which is known to have excellent magnetic and mechanical properties and to insulate so well that any kind of current may be used. It can be worked readily with a diamond tool.

Note on electromagnetic induction and relative motion. S. J. Barnett. Phys. Rev., p. 527 (Mar. 19, 1920).

A further discussion of the results obtained in an investigation published in the Physical Review, August 1918, p. 95.

Further experiments on magnetization by rotation. By S. J. Barnett. Abstract of paper read before Philosophical Society of Washington, Oct. 9, 1920.

This paper is a report of progress in the first part of a general investigation of the relations between magnetization and rotation designed to extend the earlier work in this field, to obtain more precise results, and especially to find out whether positive electricity is partially responsible for magnetism.

In earlier papers it has been shown that, if the slowly moving electron known from other experiments is alone involved in the Amperian vortices, the rotation of a magnetic substance at an angular velocity of one revolution per second is equivalent to placing it in a magnetic field of strength 7.1×10^{-7} gauss directed along the axis of rotation. Two series of experiments made in 1914 and 1915, by a method of electromagnetic induction, gave 3.6 and 3.1, respectively, instead of 7.1, apparently indicating that negative electricity was chiefly responsible, but that positive electricity also was involved. Another series of experiments in 1916 and 1917 by a magnetometer method gave the same sign as before, but gave numbers approximately 5 and 6 in place of 7.1, thus indicating much less definitely an effect of positive electricity. A few experiments made more than two years ago at the Ohio State University, where the other work was done, with copper substituted for the magnetic substance, indicated that a part of the effect in the magnetometer experiments was due to eddy currents, the effects of which appear to have been completely eliminated in the work done by the method of electromagnetic induction. This probably accounts for at least a part of the discrepancy between the results obtained by the two methods.

New experiments were performed under superior conditions in the non-magnetic experiment building of the Department of Terrestrial Magnetism by the magnetometer method, with which alone the remainder of the paper deals; considerable improvements have been made in the completeness with which the earth's field is compensated, in the elimination of mechanical and magnetic disturbances, and in other ways. The polar position of Gauss, which was earlier thought impracticable, has been substituted for the equatorial position, as it makes less difficult the elimination of eddy-current effects and has other

advantages. Eddy-current effects have been more thoroughly studied by rotating copper and otherwise. The work is still in progress and other tests remain to be applied.

The most extensive observations have been made on a rod of Norway iron (for which observational curves were shown), many observations have been made on a rod of cobalt, and some on rods of cold-rolled steel. All the rods gave values near one-half of 7.1 instead of 7.1, just as in the experiments on iron by the method of electromagnetic induction, thus again apparently indicating an effect of positive electricity. Satisfactory experiments on nickel have not yet been made.

It is interesting to observe that, while all the sources of trouble have not yet been removed, the method is so sensitive that, in the later part of the night, when the extraneous magnetic disturbances are least, the effect can be measured at even very small speeds. Curves between the scale readings for right and left handed rotations and the time were exhibited, showing clearly the effect for cobalt at the speed $\frac{3}{4}$ revolution per second.

The paper closed with a reference to recent experiments on the converse effect (rotation by magnetization). These experiments on the theory which has been adopted by the investigators, but which involves an uncertain assumption with reference to the seat of the reaction to the resultant electron momentum produced on magnetization, also appear to indicate an effect of positive electricity of the magnitude given above.

Design and construction of a sine galvanometer for the precise determination of the horizontal component of the Earth's magnetic intensity. S. J. Barnett. (See p. 307).

The construction of the instrument briefly described in the annual report for 1919 is now well advanced. The only modification of the design published in 1919 consists in replacing the marble magnetometer-box and suspension with air damping, by a copper box and suspension with electromagnetic damping. This modification, in the interest of simplicity, has been made possible by the fact that copper can be cast free from iron in the foundry of the Department of Terrestrial Magnetism.

Procedure at the magnetic observatories of the Carnegie Institution of Washington. L. A. Bauer. Terr. Mag., vol. 24, No. 4, 149–153 (Dec. 1919).

Until some recommendation has been made by the International Section of Terrestrial Magnetism and Electricity, it has been decided to adopt the following procedure at the magnetic observatories of the Department of Terrestrial Magnetism:

(1) At each observatory, the magnetograph tabulations will apply to the local day corresponding to the nearest standard (15°) meridian.

(2) In scaling magnetograms, the mean ordinate shall be taken as applying to a 60-minute interval centering at the half-hour of the standard time adopted. (Thus the first ordinate will be for the interval from 0^h to 1^h standard time.)

Accordingly, at Watheroo (longitude, 7^h44^m E.), the first mean ordinate will be for the interval 0^h–1^h, 120th M. T. East, or 16^h–17^h G. M. T. of preceding day; for Huancayo (longitude, 5^h01^m W.), it will be for 0^h–1^h, 75th M. T. West, or 5^h–6^h G. M. T. Thus with these two observatories, the resolution passed at Innsbruck in 1905, at the meeting of the Commission on Terrestrial Magnetism and Atmospheric Electricity of the International Meteorological Committee,[1] will be followed in effect at 11 observatories,

[1] *Terr. Mag.*, vol. 10, 1905, p. 198.

encircling the globe, as also practically the same procedure with regard to the hourly tabulations, will be followed.

In order to furnish to those observatory directors who prefer mean 60-minute ordinates beginning with the interval $0^h30^m-1^h30^m$, G. M. T., for a limited number of days, as for example, the so-termed international five quiet days each month, these data will likewise be given in the Department's publications.

It has furthermore been decided, in accordance with the principle to keep observational means and manipulations as simple as possible, to register, as is done at the vast majority of observatories, changes in declination (D), in horizontal intensity (H), and in vertical intensity (Z) instead of changes in the three rectangular intensity components (X,Y,Z), all of which are subject to temperature changes. It has been found very helpful to have at least one magnetograph record (D) not affected by temperature changes, and so immediately available.

The cruises of the *Carnegie*. L. A. Bauer. World's Work, vol. 39, No. 3, 280-301 (Jan. 1920). (A popular account of the cruises and work of the *Carnegie* up to 1920. The article contains numerous illustrations pertaining to the vessel, instruments, cruises, ports, etc.)

Résumé of observations concerning the solar eclipse of May 29, 1919, and the Einstein effect. L. A. Bauer. Science, n. s., vol. 51, No. 1317, 301–311 (March 26, 1920).

Preliminary results of analysis of light deflections observed during the solar eclipse of May 29, 1919. L. A. Bauer. Science, n. s., vol. 51, No. 1328, 581–583 (June 11, 1920).

Further results of analysis of light deflections observed during the solar eclipse of May 29. 1919. L. A. Bauer. Science, n. s., vol. 52, No. 1337, 147 (Aug. 13, 1920).

Concerning results of Observed Gravitational Light Deflections.[1] Louis A. Bauer.

The results of the light deflections observed by the British expedition at Sobral, Brazil, during the total solar eclipse of May 29, 1919, as derived from Crommelin's 7 photographic plates, using a 4-inch lens of 19-foot focus and an 8-inch cœlostat, gave a deflection at the Sun's limb of 1".98, or about 14 per cent higher than the value (1".74) derived from the Einstein theory of gravitation. Resolving the published deflections in right ascension and declination, for each of the 7 stars concerned, into two components, one along the radius vector to the center of the Sun, the *radial component*, and the other transverse to the radius vector, the *non-radial component*, it was noted independently by Dr. Silberstein and the author that the observed total deflections were not strictly radial, the non-radial components being of appreciable magnitudes and varying in a strikingly systematic manner from star to star. The observed deflection appeared to be a function not simply of distance alone, as required by the Einstein law, but also of the star's position-angle.

With the view of determining the possible bearing upon the observed light deflections of the geophysical observations made by the expeditions of the Carnegie Department of Terrestrial Magnetism at Sobral, Brasil, and Cape Palmas, Liberia, and by the Brazilian expeditions at Sobral, an analysis was undertaken by the Department of Terrestrial Magnetism. It may be recalled that the question was raised and discussed in *Nature*, by various British investigators, whether there might not be appreciable abnormal refraction effects in the Earth's atmosphere as caused by meteorological changes during totality.

[1]Presented in the author's absence by Dr. Frederick Slocum at the meeting of the American Astronomical Society, September 3, 1920.

On the basis of the information in the British printed report,[1] we have made an independent reduction of the photographic measures resulting from Crommelin's plates.

The non-radial effects, as resulting from our calculations, are found to be on the average about one-third of those derived from the British printed results and as given in the seventh column of Table II of the article in *Science* of June 11, 1920 (see page 583); in brief, our non-radial effects are on the order of the error of observation, so that they may be regarded as non-existent until other observational evidence is obtained.

Comparing the revised radial-light deflections resulting from all reductions with those computed on the basis of the Einstein theory of gravitation, it is found that generally the observed deflection is greater than the theoretical value.

Star 11, the most distant star, according to the British reductions showed a deflection agreeing better with the value calculated on the basis of the Newtonian mechanics, but it now shows a deflection agreeing better with the Einstein value. In brief, the results of all reductions would lend additional support to the conclusion reached by the British astronomers, namely, that, as judged by their best photographic plates, the light deflections observed during the solar eclipse of May 29, 1919, accorded better with the calculated values on the basis of the Einstein theory than on the basis of the Newtonian mechanics.

The scientific work carried out in the Pacific Ocean by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. L. A. Bauer. (Prepared for the First Pan-Pacific Scientific Conference, held at Honolulu, August 2–20, 1920.)

Cruises—During the period August 1905 to May 1908, three cruises were made on the chartered brigantine, the *Galilee*, aggregating about 64,000 nautical miles. The aggregate length of the cruises made on the specially constructed non-magnetic vessel, the *Carnegie*, at various times between 1912 and 1918, is about 85,000 nautical miles. During the present cruise of the *Carnegie* she will traverse in 1920-21 about 27,000 nautical miles in the Pacific Ocean. Accordingly, the total length of the cruises of the *Galilee* and the *Carnegie*, between 1905 and 1921, will be about 176,000 nautical miles, covering the Pacific Ocean between the parallels of 60° north and 60° south.

Observational work.—The observational work comprises chiefly the subjects of terrestrial magnetism, atmospheric electricity, and atmospheric-refraction observations. In addition, however, such auxiliary observations are made as available time permits, for example, meteorological observations, examination of the radioactive content of the atmosphere, experimental investigations pertaining to possible gravimetric observations, special oceanic phenomena, etc.

The magnetic observations at sea comprise the determination of the magnetic declination, the dip of the magnetic needle, and the strength of the Earth's magnetic field. Furthermore, from the intersections of cruises made at various times, the changes in the magnetic elements are determined in order that the necessary corrections may be applied to current magnetic charts. Similar observations are made at all ports visited by the vessel.

Results.—The methods of observation used have reached such a state of perfection that it is possible to make magnetic observations at sea almost

[1] "A Determination of the Deflection of Light by the Sun's Gravitational Field from Observations made at the Total Eclipse of May 29, 1919," by Sir F. W. Dyson, F. R. S., astronomer royal; Professor A. S. Eddington, F. R. S., and Mr. C. Davidson. Phil. Trans. R. S., London, Ser. A, vol. 220, pp. 291–333.

with the same accuracy as in land work. Special emphasis has been placed upon reducing the observations promptly, and, in fact, the chief results are made known to the leading hydrographic establishments within a few months after the observations have actually been made.

Errors of importance to mariners in the magnetic charts used have been disclosed from time to time, as also matters of general geographical interest. For fuller information reference must be made to the annual reports of the Department, and especially to Volume III of Researches of the Department of Terrestrial Magnetism, "Ocean Magnetic Observations 1905–1916 and Reports on Special Researches." This latter volume contains a chart showing the tracks of the chief vessels engaged in exploratory work in the Pacific Ocean during the past 75 years. Volume IV of the Researches, giving an account of the cruises and work between 1917 and 1920, is in preparation.

Results and analysis of magnetic observations during the solar eclipse of May 29, 1919. By Louis A. Bauer.[1]

With the aid of magnetic data from 9 stations within the region of visibility of the solar eclipse of May 29, 1919, 5 of these stations being those at which observations were made by the expeditions of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, and from about 18 cooperative stations distributed outside the region, the following main conclusions were drawn:

(*a*) Magnetic effects of appreciable and determinable magnitude were observed during the solar eclipse of May 29, 1919, at stations inside the region of totality as well as at certain stations in the sunlit region, the magnitude and character of the effects being similar to those observed during previous solar eclipses and showing a distinct connection with the eclipse circumstances. The magnetic data for stations in the night region of the globe did not exhibit similar effects.

(*b*) There were two principal variations (with some subordinate ones), as shown especially at stations near the totality-belt, having periods approximating that of the entire eclipse (5^h10^m), and that of the local eclipse (on the average about 2 hours from first to last contact). There are evidences that the effects continued for some time after the end of the eclipse at sunset on the southeast coast of Africa. The amplitude (semi-range) of the short wave was, on the average, about one-half of that for the long wave. In the case of the magnetic declination, for example, the amplitude of the long wave for stations inside or near the totality-belt approximated, on the average, 1 minute of arc, which was equivalent to a horizontal deflecting force of about 0.01 per cent that of the average west-east component of the Earth's magnetism.

(*c*) A preliminary analysis of the magnetic effects at stations within the region of visibility, or in close proximity, showed that the effects in declination and horizontal intensity were similar to those produced by a north-end attracting focus located in the vicinity of the shadow-cone. With the aid of the vertical-intensity effects it was found that the eclipse magnetic system was composed of an external and an internal system of forces. At 12^h30^m G. M. T., May 29, 1919, just before the maximum development of the eclipse system, the north-end attracting focus of the external system was located east-southeast of the shadow-cone, and that of the internal system was to the northward of the cone and approximately northward of the point where

[1] Presented before the Philosophical Society of Washington, October 9, 1920. See Terr. Mag., Sept. 1920, pp. 81–98.

the Sun and the Moon were in the zenith. The momentarily increased magnetization of the Earth for stations near the belt of totality of 0.012 per cent at 12^h30^m corresponded to the amount associated with about a 6 per cent decrease in solar radiation.[1] Equally interesting results were disclosed at other times; invariably the positions of the foci of the disturbing forces could be related to the momentary position of the shadow-cone. The indications are that the complete analysis of the eclipse magnetic system will show that it has characteristics analogous to those exhibited by the systems causing the solar-diurnal and the lunar-diurnal variations of the Earth's magnetism.

Description of glass magnetogram scale used by the Department of Terrestrial Magnetism. J. A. Fleming. Terr. Mag., vol. 24, 154–156 (December 1919.)

The glass magnetogram scale described is to facilitate reading quickly to the nearest 0.1 mm. the mean ordinates for 60-minute intervals on magnetograms in accordance with the procedure adopted for the magnetic observatories of the Carnegie Institution of Washington.[2] These scales, as constructed in the instrument shop of the Department of Terrestrial Magnetism, are somewhat similar to the type introduced by the Potsdam Magnetic Observatory and as used by the United States Coast and Geodetic Survey. The type of scale is described in detail, as well as the method used in measuring magnetograms.

The construction and equipment of the Watheroo Magnetic Observatory in Western Australia. J. A. Fleming and W. F. Wallis. Terr. Mag., vol. 25, 1-6 (March 1920).

The Director of the Department visited Australia in 1911 and conferred with those interested in geophysical investigations. As the result of these conferences, Western Australia was chosen as the site of the Department's first observatory. The general region within which the proposed observatory was tentatively specified to be was between 28° to 36° south latitude and 114° to 118° east longitude.

The necessary field-work in the examination and selection of a site conforming as nearly as is possible to the requirements was undertaken by Mr. Wallis, with the assistance of Observer Parkinson, in August 1916. It was not until early in March 1917 that the site at Watheroo was finally selected. The site is about 12 miles by road westward of Watheroo, 132 miles from Perth, on the Midland Railway, and in latitude 30° 18′ south and longitude 115° 53′ east of Greenwich, on a fine, level stretch of sand-plain, clear of timber, and covered only with coarse grass and low bushes.

The observatory buildings, as constructed under Mr. Wallis's direction and supervision, in accordance with designs developed by Mr. Fleming, consist of the following: (*a*) variation observatory and office; (*b*) absolute observatory; (*c*) observers' quarters; (*d*) storehouse and workshop; and (*e*) miscellaneous small buildings, including stable, laundry, etc. All are of frame construction, and (*a*) and (*b*) are strictly non-magnetic. As it was not possible to get contractors to offer bids on non-magnetic construction, Mr. Wallis found it necessary to purchase his own materials, engage carpenters, and carry on the work himself. Detailed descriptions and illustrations of plans and the finished buildings are included.

[1] Terr. Mag., vol. 20, 1915, p. 149.
[2] *Cf.* L. A. Bauer, "Procedure at the Magnetic Observatories of the Carnegie Institution of Washington," Terr. Mag., vol. 24, 149–153, 1919.

The observatory was completed and the magnetic variometers installed by January 1, 1919. The absolute instruments and the registering instruments are described in detail.

Magnetic storm of December 15, 1919, as recorded at the Watheroo Magnetic Observatory. E. Kidson. Terr. Mag., vol. 25, 14–15 (March 1920).

Magnetic disturbances, earthquake records, and aurora at the Watheroo Magnetic Observatory, March 1920. E. Kidson. Terr. Mag., vol. 25, 61–62 (June 1920).

These two communications give in detail the times of beginning and ending, with approximate ranges, for the three magnetic elements as recorded at the Watheroo Magnetic Observatory for the magnetic storms of December 14, 1919, March 4 to 5, March 14 to 15, and March 22 to 23, 1920. The most severe of these storms was that on March 22 to 23. The notes accompanying aurora and earth-current disturbances affecting the telegraphic service in Australia are given. Particulars concerning earthquake records made on the magnetograms of the observatory are given for such records on May 6, August 29, September 1, 1919, and February 2, 1920.

Earthquakes recorded at Watheroo Observatory, May 1920. E. Kidson. Terr. Mag. vol. 25, 142 (Sept. 1920).

This article gives particulars with reference to the earthquakes of May 11 and 13, 1920, recorded on the magnetograph of the Watheroo Magnetic Observatory.

Comments on Dechevrens's Electric Tide Observations. S. J. Mauchly. Terr. Mag., vol. 24, p. 179 (Dec. 1919).

In a brief note the author points out that neither of Father Dechevrens's letters appearing in the Journal of Terrestrial Magnetism for December 1919 (pp. 175 and 178, respectively) contains evidence which enables one to decide whether the currents observed by him at Jersey[1] are of electromagnetic or electrolytic origin. Observations were also suggested, the results of which, it is believed, would shed some light on the origin of the currents in question.

Results of Atmospheric-Electric Observations made during the Solar Eclipse of May 29, 1919. S. J. Mauchly and Andrew Thomson. Terr. Mag. vol. 25, 41–48, (1920). (Abstract) Phys. Rev., vol. 15, 525–526 (1920). (Abstract of paper presented before the American Physical Society, Washington, April 23, 1920).

This paper is based upon observations made at Sobral in northeastern Brazil in accordance with the general plan of the Department of Terrestrial Magnetism for magnetic and electric observations during the solar eclipse of May 29, 1919.

Sobral (long. 40° 20′.8 W., lat. 3° 41′. 6 S.) is located in the belt of totality, about 90 km. from the coast, and has an elevation of less than 100 meters. The eclipse, at Sobral, began at 8^h4^m L. M. T. (10^h45^m G. M. T.) and ended at 10^h47^m L. M. T. (13^h29^m G. M. T.). The duration of totality was 5.3 minutes, mid-totality occurring at 9^h19^m L. M. T. (12^h00^m G. M. T., civil).

The atmospheric-electric elements under observation consisted of positive conductivity, negative conductivity, and potential gradient. The apparatus and methods used were in general the same as those employed by the authors at Lakin, Kansas, during the solar eclipse of June 8, 1919[2], except that the potential-gradient observations during the eclipse were made at intervals of one-half minute, instead of 2 minutes as at Lakin, and that a special form of

[1]See also: M. Dechevrens, Terr. Mag., vol. 23, pp. 37–39, 1918; Terr. Mag., vol. 23, pp. 145–147, 1918; Comptes Rendus, vol. 167, pp. 552–555, 1918; Terr. Mag., vol. 24, pp. 33–38, 1919. E. G. Bilham, Proc. Roy. Soc., vol. 94, pp. 165–181, 1918; Proc. Roy Soc., vol. 94, pp. 476–478, 1918; Q. J. R. Meteor. Soc., vol. 44, pp. 171–189, 1918. S. J. Mauchly, Terr. Mag., vol. 24, p. 100, June 1919.

[2]Terr. Mag., vol. 24, March and June 1919.

insulator was designed for supporting the ionium collectors used in the potential-gradient observations. This insulator was provided as a precaution against insulation troubles due to rain, extreme humidity, and the activities of small insects, and proved to be entirely satisfactory. The apparatus used for potential-gradient observations was standardized by the method described by Simpson and Wright.[1]

The actual observations were made by Mr. Thomson, assisted by Mr. Antonio Lima. On May 29 the observations were made, as nearly continuously as was consistent with adequate control observations, from sunrise until middle of the afternoon. On all other days from May 24 to June 2, inclusive, regular observations for comparison purposes were made hourly, for periods of 20 minutes each, throughout the forenoons. Average meteorological and atmospheric-electrical conditions prevailed on May 29, except that the sky was overclouded just before and during the first half of the eclipse. If this is taken into account the general results may be given as follows:

(*a*) The potential gradient showed a well-formed minimum which began with totality and continued until about 20 minutes after totality. The values observed during this period were about 20 per cent lower than a mean value derived from the two 20-minute periods which immediately preceded and followed it, respectively, and also lower, in about the same proportion, than the mean value obtained from the observations for the corresponding periods on comparison days.

(*b*) During the above period of minimum value the fluctuations of the potential-gradient were very much smaller than during the two similar periods referred to under (*a*).

(*c*) If the values of the positive and negative conductivities observed during a period of about 15 minutes just following totality are compared with the mean obtained from two periods of equal length just before and shortly after the one under consideration, it appears that there was, during this period, an increase of the order of 20 per cent for both. A similar remark applies if the comparison is based on the average value for the given time of day as obtained from May 24 to June 2.

(*d*) The air-earth current-density, as computed from the potential-gradient and total conductivity, showed more constancy and adherence to the normal station value during the period in which the obscuration of the sun was at least 50 per cent than for any equal period of the day of the eclipse.

From the above it appears that the results for May 29, 1919, at the Sobral station are in general agreement with those obtained at Lakin, Kansas, during the eclipse of June 8, 1918,[2] notwithstanding the marked differences between the two stations as regards latitude, elevation, general topography, and distance from sea.

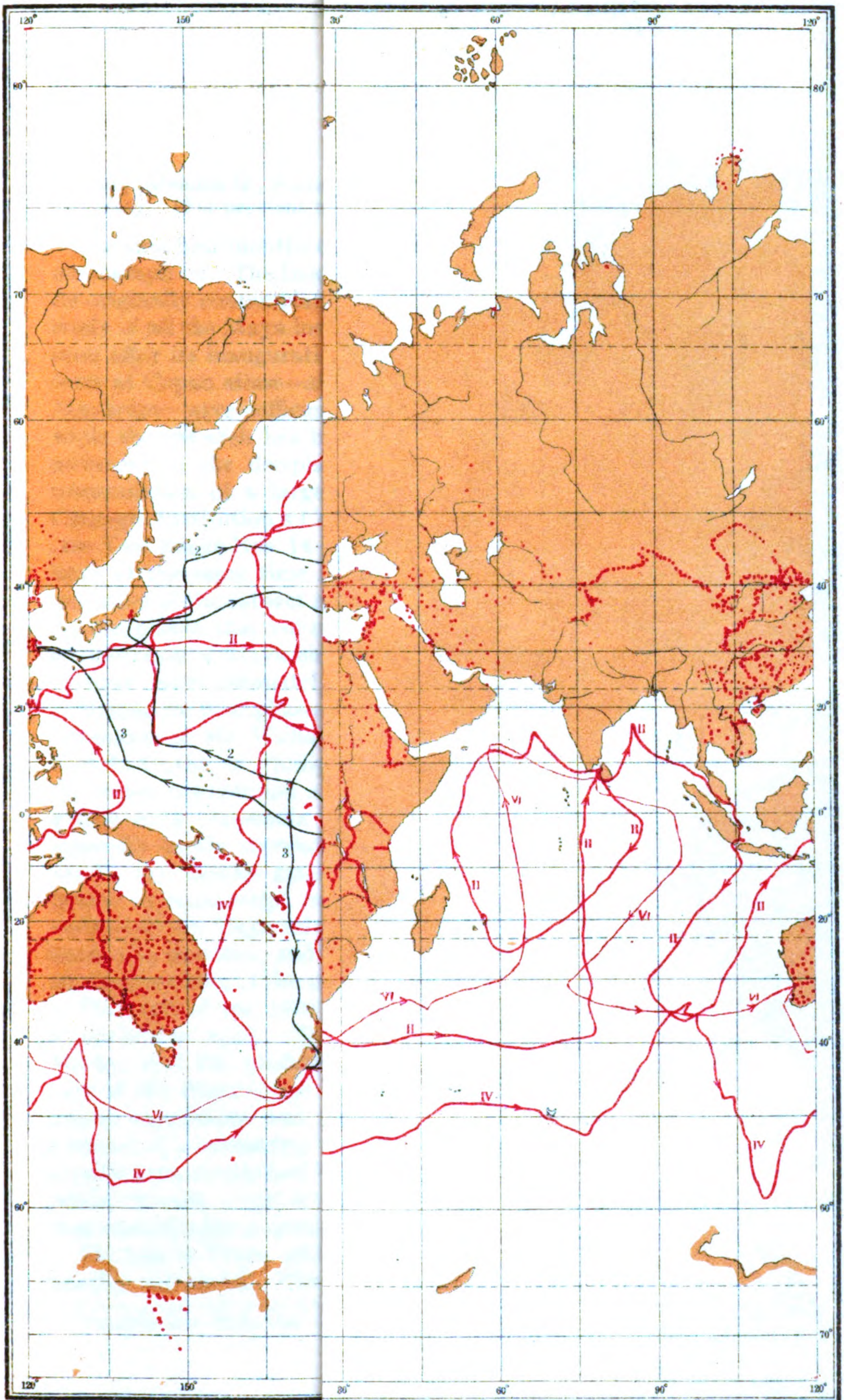
A cruise on the brigantine *Carnegie*. N. Meisenhelter. National Marine, vol. 15, No. 6, 10–18 (June 1920).

Earthquake of April 30, 1919, as recorded on the magnetogram at the Watheroo Magnetic Observatory. W. F. Wallis. Terr. Mag., vol. 24, 175 (December 1919).

This note gives the particulars of the earthquake effects registered on the magnetograph record for April 30, 1919, at the Watheroo Magnetic Observatory. This record is doubtless that of the earthquake and tidal wave which swept Pan-Gai, a town in one of the islands of the Tonga group approximately 4,640 miles east-northeast of the Observatory.

[1] Proc. R. Soc. A., vol. 85, p. 182, 1911.

[2] Terr. Mag., vol. 24, p. 96, June 1919; Annual Report of the Director of the Department of Terrestrial Magnetism for 1919, p. 307.



)05–1920 (October).

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ARCHÆOLOGY.

Morley, Sylvanus G., Santa Fe, New Mexico. *Associate in American Archæology.* (For previous reports see Year Books Nos. 13–18.)

The first four months of 1920 were devoted to the completion of the monograph on "The Inscriptions at Copan,"[1] which appeared in April. As originally contemplated, this investigation was to have included a study of all the Maya inscriptions (see Year Book No. 13, p. 333), but soon after its inauguration it became apparent that the hieroglyphic texts at Copan alone—about 40 per cent of the Corpus Inscriptionum Mayarum—were sufficient to merit monographic treatment. Meanwhile the research has been broadening in other directions. Recent advances in the decipherment of previously unknown glyphs, the accumulation of a large amount of new material gathered by the Carnegie Institution's Central-American expeditions for 1915 to 1920 (see Year Books Nos. 14–18), while delaying publication of the results, have at the same time made possible a much more exhaustive presentation of the subject and the inclusion of much new related matter. As completed, this volume with its appendices presents a standard cross-section of Maya chronology to which all other ancient American cultures must ultimately be referred for their true positions in time.

During the final phases of this investigation Mr. Morley had the collaboration of Mr. William Gates, of Point Loma, California, and Dr. Carl E. Guthe, of Phillips Academy, Andover. Mr. Gates compiled the index, contributed a study of the distribution of the Maya linguistic stock (Appendix XII), and assisted in the preparation of the appendix on the correlation of Maya and Christian chronology (Appendix II), besides generously placing his large and important collection of manuscript material at the author's service. Dr. Guthe verified all the Maya calculations, as well as all the bibliographic references and citations, and spent the month of April in Washington on the final revision of the page proof.

The staff of the 1920 Central-American expedition took the field at the end of April. The objectives of the party (composed of Mr. Morley and Dr. Guthe) were, first, the exploration of the northern part of the Department of Peten, Guatemala (into which no archeological expeditions had penetrated for the past four years), for the purpose of ascertaining whether any new sites with associated hieroglyphic monuments had been discovered by chicle-bleeders during this period; second, a visit to the village of Copan, Honduras, to present to that municipality a specially bound copy of publication No. 219.

The trip to Peten, although less than a month in duration, was unusually successful. The expedition first visited the capital of the

[1] Carnegie Inst. Wash. Pub. No. 219, quarto, xiv+644 pp., 34 pls., 93 text figs., 1920.

department—the island village of Flores—and placed itself in touch with the local authorities. No large sites had been discovered in the central part of Peten during the past four years, and the expedition returned to the frontiers of British Honduras, preparatory to making another trip into the northeastern corner of the department, which offers the most promising field for exploratory work. At Benque Viejo, British Honduras, information was received of a new site, about 60 miles to the northwest, and a mule-train was engaged and the party proceeded thither during the last fortnight in May. The new site, to which the name Xultun[1] was given, proved to be of great importance, no less in fact than a city of the second class with two principal plazas, 50 subsidiary courts, and 18 sculptured monuments. It has more structures, covering a larger area, than either Piedras Negras or Quirigua, and has more sculptured monuments than either Nakum or Palenque. It is larger than La Honradez in the same region, and was probably the largest city of the Old Empire in northeastern Peten.

The inscribed monuments are the most important feature of the new city. They are found around the sides of the two principal plazas, 10 in Group A (fig. 1) and 8 in Group B, all the earlier monuments being in the latter and all the later ones in the former. Of these 18 sculptured stelæ (no plain stelæ were found at the site), 8 have Initial Series dates, 2 have Period-Ending dates, and 8 are as yet indeterminate. Of the Initial Series stelæ, the dates of three have been surely deciphered, and a fourth probably so, as follows:

					Approx.
Group A	Stela 3	10. 1.10.0.0	4 Ahau	13 Kankin	600 A.D.
Group A	Stela 10	10. 3. 0.0.0	1 Ahau	3 Yaxkin	630 A.D.
Group B	Stela 11	9.15. 0.0.0	4 Ahau	13 Yax(?)	472 A.D.
Group B	Stela 13	9.14. 0.0.0	6 Ahau	13 Muan	452 A.D.

Stela 10 (fig. 2, right half) is of unusual importance, since it is the latest monument, by 20 years, yet reported from any Old Empire site. The date is recorded by an Initial Series, the coefficients of which are all bar-and-dot numerals, and there is no doubt as to the accuracy of the reading given. It is interesting to note that the discovery of this monument proves that the close of the Old Empire was contemporaneous with the beginning of the New Empire, as suggested in "The Inscriptions at Copan," since the date on the Temple of the Initial Series at Chichen Itza, in northern Yucatan (New Empire), is just 10 years *earlier* than the date of Stela 10 at Xultun (Old Empire); in a word, the monumental series of the Old and New Empires are now seen to have overlapped by at least 10 years. On the basis of the dates thus far deciphered, the city would seem to have had a period

[1] *Xul* is the Maya word for "end" or "close," and *tun* the word for stone. Xultun, therefore, may be translated "end stone" or "last stone," the name being suggested by the fact that the latest Old Empire monument yet reported is Stela 10 at this site.

of occupation of about 180 years, being founded in the Middle Period of the Old Empire and occupied down to the close of the Great Period, possibly even being the last Old Empire city to be abandoned.

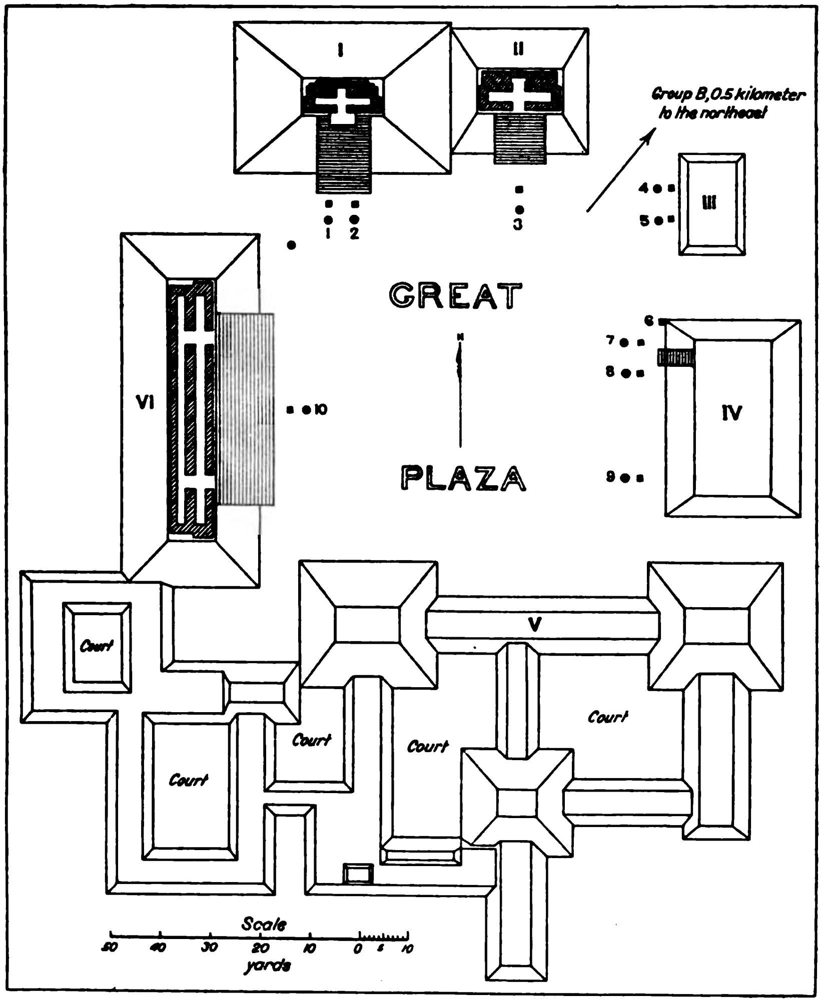

FIG. 1.—Plan of the Great Plaza of Xultun (Group A), showing location of principal temples (Roman numerals) and sculptured monuments (Arabic numerals).

More than half of the Xultun stelæ (11 out of the 18) have fallen with their sculptured faces down, so that they are probably in an excellent state of preservation. The 1920 expedition, with the means at its disposal, was able to turn only two of these, but the almost perfect condition of their relief and the beauty of the subjects portrayed (an elaborately costumed deity, ruler, or priest, with accompanying inscription) justify the belief that when the expedition returns next year to turn over the others, an unusually fine group of sculptured panels will be recovered.

Before leaving Peten, notices in Spanish to the chicle-workers, to be on the lookout for new sites during their excursions into the bush during the current rainy season, were extensively distributed in the frontier towns and chicle camps. Adequate rewards were offered for such information, and it is anticipated that other new sites will be located in the region as a result of this measure.

The second trip (to Copan, Honduras) also had satisfactory issue. Upon the arrival of the expedition at the village, the alcalde for the current year, Don Tobias Guerra, arranged for a special session of the cabildo, all the villagers being invited to attend. At this meeting "The Inscriptions at Copan" was formally presented to the municipality in the name of the Carnegie Institution of Washington and accepted by the village authorities. This ceremony was duly entered into the Book of the Acts of the Cabildo of Copan, and a certified copy of the act was furnished for deposition in the archives of the Institution.

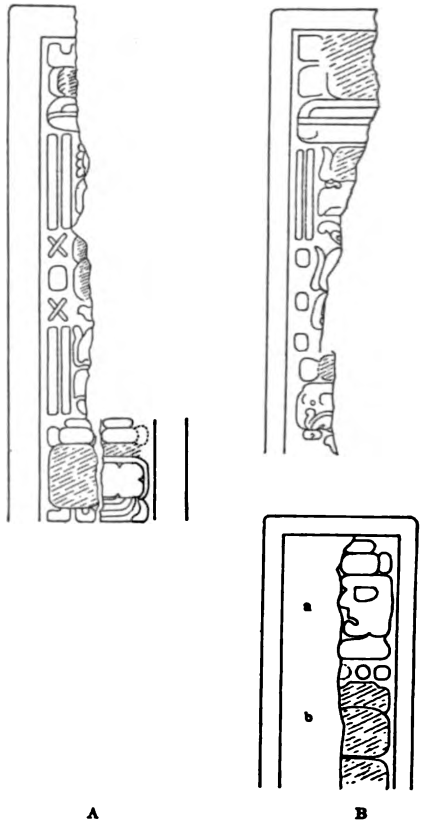

FIG. 2.—A, Stela 3, Xultun, recording the date 10.1.10.0.0 of the Maya Era, approximately 600 A. D. B, Stela 10, Xultun, recording the date 10.3.0.0.0 approximately 630 A. D.

During the past five years Mr. Morley has made annual visits to Copan and the villagers have warmly cooperated in the Institution's investigations there. Equally friendly relations have been established with the central authorities at Tegucigalpa, the capital, and the way paved for closer cooperation in the future.

The field season closed with a visit to Guatemala City, where arrangements were perfected with the Guatemalan government, through the Ministry of Foreign Relations, for continuing the archæological exploration of Peten next season, and a permit was secured for excavating anywhere in the department, it being understood that all specimens recovered should remain in the republic. There exists a friendly and sympathetic interest in the Institution's activities in both Guatemala and Honduras (the southern Maya field), and the opportunity for intensive archæological investigations in either of these countries was never so favorable as it is now.

BIBLIOGRAPHY.

Garrison, Fielding H., Army Medical Museum, Washington, District of Columbia. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–18.)

The Index Medicus for 1919 (second series, Volume XVII) contains 984 pages, with an index covering 183 pages, as compared with 776 pages and 153 pages respectively for 1918, and 682 and 134 pages respectively for 1917. The rapid increase in size of these successive volumes is largely due to huge invoices of German periodical literature, which have been received through various channels since the signing of the armistice. In striking contrast with the medical periodical literature of England, France, and other countries during the war period, this body of German literature has remained as constant in quantity as during the pre-war period. Owing to the different devices which had to be employed to obtain this literature during the war and the different channels through which it was obtained, the indexing of articles in the periodicals has been somewhat irregular as to sequence of dates, but it is believed that all the important German periodicals for 1919 and a large part of those for 1920 will be indexed in the current volume of the Index Medicus (1920, Vol. XIX). Since the beginning of the Russian revolution, no periodicals or other medical literature have been received from Eastern Europe, and it is doubtful if these periodicals will be available for a long time to come.

During the past few years, criticisms have been received of the arrangement of subjects in the monthly numbers in the Index Medicus, the general trend of opinion being that, for practical purposes, an alphabetical arrangement of subjects, as in the Annual Index of the journal or the Index Catalogue of the Surgeon General's Library, would be preferable to the present arrangement of subjects, which is analogous to the arrangement of books on the shelves of medical libraries. At the request of the editor, the Carnegie Institution of Washington sent out duplex postal cards to subscribers to the Index Medicus, requesting a definite decision as to the adoption of a quarterly form of issue for the journal, with the subjects arranged in alphabetical order, or its continuance in its present form. In spite of many interesting and informing letters as to the advantage of the older plan to the more studious class of readers, the larger proportion of replies was in favor of the former alternative. After due consideration of the matter, it has been decided to publish the Index Medicus in quarterly form, with alphabetical arrangement of contents, indexing itself as to subjects, after January 1, 1921. In this form, the journal will have an annual index of authors as formerly, but references under any given subject may be easily found by turning to the successive four numbers. With a

proper list of subjects and cross-references to orient the reader as to the location of titles, it is believed that this will be a labor-saving device and that it will simplify many of the bibliographic problems which have perplexed both the editor and the readers.

In connection with increased literature on various subjects, the introduction of such new titles as "Entomology," "Medical Sociology," "Encephalitis lethargica," "Food Economics," "War Bread," etc., is self-explanatory.

BIOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3–18.)

The subjects under investigation during the past year have been substantially the same as in the previous year, viz: (1) a study of linkage, which causes characters either to go together or to stay apart in heredity, and (2) a further study of size inheritance.

Progress has been made in determining more precisely the linkage relations in rats of three genes which occur in a common linkage system. It has been found that the arrangement is probably linear. A large stock of animals has been reared for the purpose of gaining a decisive answer to this question. A convenient and accurate method of describing linkage strength has been devised. The linkage strength of two linked genes of mice has been determined. A pair of linked genes has been discovered in rabbits. The characters involved are English pattern of white spotting and dilution. The indicated linkage strength is 23 on a scale of 100. Dr. L. C. Dunn, who has been associated with these investigations for several years, took up the work of biologist at the Storrs (Connecticut) Agricultural Experiment Station in March. The results of his investigations with mice will shortly be published. Material for a study of size inheritance in rabbits has been accumulated during the past three years and is now being studied. It is hoped that the results will be ready for publication within a few months. A considerable part of the work conducted during the past 17 years under the auspices of the Institution will be summarized or reviewed in a second edition, now in press, of "Genetics and Eugenics." Four short papers have been published during the year.

Mann, Albert, Washington, District of Columbia. *Continuation of investigations and preparations for publication of results of work on Diatomaceæ.* (For previous report see Year Book No. 18.)

The large number of requests for information and for cooperative study of the diatoms during this first year of research has exceeded the resources of the office. This has been partly due to the fact that the writer, although well supplied with laboratory help, has so far been

unable to find a scientific assistant who could take part in the actual investigation of new material. A considerable portion of the year has necessarily been given to meeting some of these demands for cooperative work, and certain plans for individual study, made a year ago, have had to be postponed.

A good deal of attention has nevertheless been given to one line of independent study, that of the marine diatoms of the Philippine Islands. A large number of new dredgings has been examined and has resulted in finding about 30 more new species, as well as increasing the list of species already named. This has made it necessary to postpone the publication of "The Diatoms of the Philippine Islands" until these additional species have been photomicrographed and described; but the greater completeness of the report will fully justify the delay.

A series of specimens from the fossil diatom beds of Lompoc, California, has been examined at the request of Dr. David Starr Jordan, of Stanford University. The original purpose of this study was to see if changes or peculiarities in the diatom flora at different levels would throw light on the cause of a sudden destruction of immense numbers of herring, the fossil remains of which constitute a narrow stratum about 900 feet above the floor of this great deposit. The Lompoc bed has a depth of something over 1,400 feet and an area approximating 12 square miles. The herring, to which Dr. Jordan has given the name *Xyne grex*, were all adults and evidently had all been killed at the same time, as their carbonized remains are compacted into one narrow layer. The cause of this simultaneous slaughter of such a large quantity of fish must have been an exceptional one; and as the material in which their remains are embedded is pure diatomaceous earth, a record of the holocaust was sought for in the diatom layers, especially those adjacent to the *Xyne grex* stratum. In order to avoid any unconscious bias in interpreting such evidence as a study of the diatoms might afford, the literature on the subject was not consulted until after the research had been made.

The Lompoc bed is a marine deposit, fairly rich in species, and made up almost wholly of plankton diatoms. It is remarkably free from sand, clay, or organic detritus, showing that its material was not transported to its place of deposit by rapid or turbulent currents. The absence of any fresh-water species proved that no streams or rivers emptied into the basin. The species found were characteristic of northern latitudes and indicated that the waters had come from a coastal current from the north. The presence of a large number of abnormal and misshapen diatoms in the *Xyne grex* layer and the layers mmediately above it was evidence that the waters were increasing in salinity, probably as the result of evaporation. These and other indications led to the surmise that the herring represented a large

migrating school of fish which, following the sea-current southward, had been swept into the inland basin where the Lompoc bed was forming, perhaps assisted by a high tide and the inward movement of surface-drift induced by a west wind; and that, being practically landlocked, they had quickly succumbed to the effects of rapidly increasing temperature and salinity—these changes being brought about by the shallow nature of the basin. Herring are known to be extremely sensitive to these influences. The facts of the topography of the Lompoc area at the period represented by the above event were found to agree with this interpretation, and it was also found to be in harmony with conclusions arrived at by wholly different lines of research.

A study and detailed report of the diatom flora of 24 samples of calcareous sand, collected in the Bahamas and along the Florida Keys as far west as Tortugas, were made at the request of the collector, Dr. T. Wayland Vaughan, of the U. S. Geological Survey. About 150 species were found, including 13 new species, figures and descriptions of which will be published at some future time. The significant fact brought out by this investigation was the evidence it afforded of the retarding effect of calcareous waters on the growth and development of diatoms. Not only was the number of species low in comparison with similar gatherings made in non-calcareous waters, but many of the individuals showed retarded development, in the imperfectly silicified character of their "skeletons" and in the frequency of misshapen and grotesque forms. Certain facts not germane to this report indicated that this retardation was probably due to an inadequate supply of silica in the waters of this locality, caused by the replacement of quartz sand by calcareous sand, and perhaps also by the further poverty of silica in the sea-water resulting from the formation of the insoluble compound, calcium silicate.

Some fresh-water samples were examined for diatoms and identifications were made for Dr. N. Gist Gee of Soochow, China.

A very interesting study was made of some living diatoms contained in atmospheric dust, brought down by a snowstorm at Madison, Wisconsin, and sent by the collector, Professor A. N. Winchell, of the University of Wisconsin. Four species were found in this dust; and it is interesting to note that two, *Hantzschia amphioxys* (E.) W. S., and *Navicula borealis* (E.) K., seem to be frequently present in atmospheric dust, both here and in Europe. Their terrestrial home is in cool sphagnum bogs and the moss on the shady side of tree-trunks.

Some diatoms of great interest were secured in material dredged at Pago Pago, Samoa, by Dr. Alfred G. Mayor.

Passing over a considerable number of small investigations made during the year for different parties, it may be well to refer here to an informal report made to the U. S. Bureau of Fisheries on the diatom flora of Woods Hole, Massachusetts. This report was based on studies

conducted at Woods Hole at the request of the Bureau of Fisheries, which are still being carried on. After several years of collecting and research, it seemed to be proper to emphasize by this report the great economic value of a thorough and continuous study of the diatom flora of the coastal waters, because of the importance of these plants to the feeding and the abundance of our edible sea-fishes. The variation in the quantity of marine diatoms in different years and at different seasons of the year, coupled with the variation in the quantity of migratory fishes at different parts of the coast, was discussed; the relative value as fish-food of different kinds of diatoms was treated, and the important question was raised as to the possibility of controlling to some degree the quantity and quality of the diatom flora at such points along our seaboard as are best adapted to the capture and transportation of marketable fish. The writer ventured the opinion that this highly important control of fish food was distinctly possible.

Morgan, T. H., Columbia University, New York. *Study of the constitution of the germ-plasm in relation to heredity.* (For previous reports see Year Books Nos. 15–18.)

The following report covers the work of T. H. Morgan, C. B. Bridges, and A. H. Sturtevant, for the year 1919–1920, on the constitution of the hereditary materials of *Drosophila*, carried out at the Zoological Laboratory of Columbia University and at the Hopkins Marine Station of Stanford University.

The maps of all four chromosomes of *Drosophila melanogaster* are being improved, both by locating more accurately already known mutant genes and by finding and placing new genes. The work has progressed so far that a revision of the first and second chromosomes has become necessary, but before undertaking this it is proposed to publish all available data concerning the third and fourth chromosomes.

A few examples will serve to show the nature of the improvements that are being made in the maps. The third chromosome has been lengthened at both ends—25 units to the left by the discovery of roughoid and 9 to the right by minute and claret. The improvement in the map of the second chromosome has consisted mainly in filling in regions where no genes or poorly workable genes were previously known. For example, two new useful dominants, "gull" and "lobe," have been found and the large gap between curved and arc has been filled by two mutants, a dominant (minute-2) and a recessive ("humpy"). The discovery of a new gene, cross veinless, in the first chromosome, lying in the gap between ruby and cut, fills up the chromosome so that we are now able to study any region of the X-chromosome without the occurrence of unobserved double crossing-over. In our first report 36 mutant genes in the first chromosome were recorded; at the present writing we have met with and examined about 125 mutant genes in this chromosome. In the fourth chromosome the attempt to obtain

the double recessive, bent eyeless, has been made on a large scale, again without success, showing either that crossing-over does not occur, or is very infrequent in this chromosome pair. However, the recent discovery of fourth-chromosome dominants gives an opportunity of renewing the attack, from a different angle.

Since the last report, 28 or more mutants of a particular type have been discovered in which dominance, minute bristles, and late hatching are present and are correlated with several other peculiarities. Despite their outward similarity in many details, it turns out that many of these mutants have very different locations in the chromosomes.

Two types of non-disjunction not yet described have been analyzed, one in the XXYY female, and the other in XXX oogonia. The latter furnishes an interpretation of a phenomenon called formerly "equational non-disjunction." Further studies of XXY females have made it probable that the Y does not influence crossing-over in the normal type of non-disjunction, but does increase crossing-over in certain types of "high non-disjunction."

During the course of the year Professor O. L. Mohr, of the University of Christiania, Norway, has carried out further work with Notch 8 (deficiency) and completed this work while with us during the past summer, at Pacific Grove, California. His study has brought to light some new and important characteristics of deficiency.

Of the many attempts that have been made during the last few years to hybridize different species of *Drosophila,* so far only one has been successful, viz, *D. melanogaster* with *D. simulans*. As already reported, the cross made one way (*melanogaster* ♀ × *simulans* ♂) gives commonly females only; the reciprocal cross (*simulans* ♀ × *melanogaster* ♂) gives males and occasional females. Since these hybrids are sterile, it is not possible to continue the experiment further; but another method of attack has been found, by which some of the mutant characters in *simulans* have been proven to be identical with certain ones in *melanogaster*. In order to do this it was first necessary to obtain as many mutant types in *simulans* as possible. About 20 mutants have been obtained, of which 6 correspond to *melanogaster* mutants already known. Since it has been shown that these mutant characters are recessive when each mutant type is crossed to the wild type of the other species, it follows that each wild type carries the normal allelomorphs of the other species. And since the hybrids between these recessive mutant races show the characteristics of the two parents, we must regard the mutant genes as allelomorphic. This means that the same gene has mutated in each species, and in the same direction; and in at least 4 of the 6 cases the mutant characters appear to be actually identical. Five of these corresponding genes of *simulans* are in the X-chromosome. Their linkage relations have been studied, and a comparison of the resulting map with that of *melanogaster*

shows that the sequence is the same in both, but that the amounts of crossing-over are somewhat different.

Among the mutants found in *D. simulans* is one, located in an autosome, that causes characteristic male parts to appear in the genitalia of the female. Such individuals fall under the general category of intersexes—the occurrence of which, in other forms, has attracted much attention in recent years; in the present instance it has been shown that the intersex is due not to disturbances in the ordinary sex-determining mechanism, but to a mutation that took place in an autosome, *i. e.*, not even in a sex-chromosome.

The stocks of *Drosophila* that are kept on hand and serve as our working material number nearly 200. The stocks represent only those types and combinations that have been found valuable for our work, and do not include all the mutant types that have appeared during the past few years. Mutants whose viability is poor are not kept longer than is necessary to place them on record. Those whose separation from other stocks or from the wild-type is uncertain or laborious are also allowed to go. To avoid the necessity of selection in every generation, in cases in which one or the other sex is sterile or dies, we have made use of the principle of balanced lethals. As a result of the balancing, such stocks appear to breed true, although they are in reality permanent hybrids.

In connection with the work of the year, it may be noted that: Dr. J. F. Nonidez has completed a careful study of the physiology and structure of the reproductive organs of *D. melanogaster;* Dr. Shelley R. Safir has completed his work on primary non-disjunction; Mr. L. C. Strong has worked out the location of the mutant roughoid; Mr. H. H. Johnson has discovered and worked out a mimic of vermilion and scarlet, called cardinal; Dr. Mary B. Stark has continued her work, though not in our laboratory, on the lethal tumor, and has discovered also a benign tumor that behaves as a Mendelian character; Mr. D. E. Lancefield has carried out work on the genetics of *D. obscura,* which has a different chromosome group from that of *D. melanogaster*, and which promises results of great importance.

CHEMISTRY.

Morse, H. N., Johns Hopkins University, Baltimore, Maryland. *Measurement of the osmotic pressure of solutions.* (For previous reports see Year Books Nos. 2–16.)

During the past year the work on osmotic pressure has been along two lines: first, the perfection of a suitable method for the measurement of osmotic pressure which would permit accurate measurements of high pressures and at the same time the rapid attainment of equilibrium pressure; secondly, the perfection of the osmotic membrane

and its support so that the osmotic pressure of solutions other than a few non-electrolytes could be measured.

The work on the first of these problems has been successful, as it has been shown that the water interferometer permits accurate and rapid measurements of the osmotic pressure of solutions. Thus the following results have been obtained on solutions of sucrose at 30° and 55.7°:

Exp. No.	Grams sugar 1000c.c. solutions.	Grams sugar 1000 g. water.	Equilibrium time.	Osmotic pressure.	Exp. No.	Grams sugar 1000 c.c. solutions.	Grams sugar 1000 g. water.	Equilibrium time.	Osmotic pressure.
	30°		*h. m.*	*atmospheres.*		55.7°		*h. m.*	*atmospheres.*
1	478.3	680	1 30	57.5	14	477.2	674	22	61.0
2	472.0	665	12	56.6	15	481.4	685	20	63.1
3	597.0	958	1 30	87.2	16	610.6	996	35	97.4
4	605.4	980	2 30	90.4	17	612.7	1,000	16	98.7
5	608.5	990	2 45	92.0	18	702.3	1,270	30	132.4
6	700.2	1,260	3 15	129.5	19	706.4	1,284	55	133.5
7	695.0	1,242	3 45	122.4	20	782.5	1,556	1 15	170.6
8	781.4	1,549	3	169.1	21	791.9	1,590	1 30	178.7
9	781.4	1,549	3 45	168.6	22	856.5	1,877	2	222.0
10	777.3	1,533	1 30	164.1	23	842.9	1,810	2 15	213.8
11	831.5	1,758	5	198.2	24	900.2	2,112	2 45	259.3
12	826.2	1,737	3 15	200.2	25	910.6	2,190	2 15	265.6
13	839.8	1,796	2 45	206.1	26	No analysis		2 15	273.0

The important feature of this work is that measurements have been made under conditions where there has been no passage of the solute into the solvent through the membrane. The point of most interest in the results is the temperature coefficient of these concentrated solutions. In the most concentrated solutions studied, it has been found that the temperature coefficient is not only less than that of an ideal gas, but so much less that the osmotic pressure of some of the most concentrated solutions is actually less at 55.7° than at 30°. Efforts are being made to extend these measurements to temperatures higher than 55.7°.

Noyes, Arthur A., California Institute of Technology, Pasadena, California. *Researches upon (1) the properties of solutions in relation to the ionic theory, and (2) the determination of the atomic structure of crystalline substances by X-rays.* (For previous reports see Year Books Nos. 2–18.)

Efforts during the past year have been primarily directed to preparing for publication the various researches completed during the war period; and seven articles describing these researches have been published in current journals.

The most important general result to which these researches have led is the substantiation of the principle that the ratio of the equivalent

conductance of a salt at any concentration to that approached at zero concentration, commonly employed as a measure of ionization, is not even approximately equal to the ionization in the case of largely ionized substances; or at any rate that this ratio is not even roughly proportional to the chemical activity or mass-action of the ions in determining equilibrium. Certain anomalies long known had previously made it evident that this conclusion must be true, but experimental data were lacking which would make possible a quantitative comparison of the conductance-ratio of these substances with their ion activities. These activities can be derived from studies of chemical equilibria or from the values of the electromotive forces of voltaic cells in which the substances are involved; but the only previously existing data of a character suitable for the comparison were those resulting from a research by MacInnes and Parker on the electromotive force of cells involving solutions of potassium chloride. The investigations on the electromotive force of cells carried out under the auspices of the Carnegie Institution of Washington have now led to additional results with three other substances of various chemical types, which enable more general conclusions to be drawn.

The following brief table shows the character of the results obtained in these researches, which were carried out at the Massachusetts Institute of Technology by Dr. James A. Beattie and Dr. Ming Chow, with the cooperation of Dr. Duncan MacInnes. Under the heading "Ion-activity coefficients" are given the factors, derived from the electromotive measurements, by which the concentration of the substances must be multiplied to give what may be called the effective concentration of the ions in determining chemical equilibrium and other thermodynamically related properties. Under the heading "Conductance-viscosity ratio" are given the above-mentioned conductance-ratios corrected for the viscosity of the solution through which the ions are moving.

Molal concentration.	Ion-activity coefficients.				Conductance-viscosity ratios.			
	KCl	LiCl	HCl	KOH	HCl	LiCl	HCl	KOH
0.001	0.98	0.98	0.99	0.99	0.98	0.98	0.99	0.99
.010	.89	.90	.93	.96	.94	.93	.97	.96
.100	.74	.78	.82	.85	.86	.85	.92	.91
.500	.64	.73	.77	.76	.78	.77	.89	.88
1.000	.59	.75	.83	.79	.74	.74	.84	.88

From these data may be drawn the general conclusions that the conductance-ratio can no longer be regarded as even an approximate measure of the activity of the ions of largely ionized substances in their

mass-action and thermodynamic relations; that this activity varies with the concentration differently in the case of different substances; and that for the present it can be determined only empirically for each substance, with the aid of measurements of chemical equilibrium, electromotive force, or freezing-point.

These results, combined with a consideration of other known facts, make it probable that the behavior of largely ionized substances can be most simply accounted for by the hypothesis that these substances are in reality nearly completely ionized, at any rate up to moderate concentrations, such as 1.0 molal. Correspondingly, the decrease in the conductance-ratio would then be due mainly to a decrease in the mobility of the ions (rather than to a decrease in their number); and the decrease in the ion-activity would be due mainly to a physical deviation from the laws of perfect solutes, these two physical effects becoming large in solutions of ions, in virtue of their large electric charges, at much lower concentrations than in solutions of ordinary un-ionized substances.

Researches to test more fully the adequacy of this hypothesis of complete ionization are being continued, not only by the electromotive-force method, but by a more thorough study of the effect of salts on the solubilities of one another.

During the past year the investigations on electrode potentials or reduction potentials in aqueous solution have been continued. These are the fundamental constants which determine the equilibrium conditions of reactions of oxidation and reduction. A research by Dr. Ernest W. Wescott on the reduction potential of plumbous and plumbic compounds has been published, and one by Dr. Charles E. Ruby on that of manganates and permanganates has been completed. Work in this direction on other combinations is still under way.

Progress has also been made on the other line of research carried on with the aid of the grants from the Carnegie Institution of Washington—that on the determination of the atomic structure of crystalline substances by X-rays. This work has been pursued by Dr. Duncan MacInnes at the Massachusetts Institute of Technology and by Dr. Roscoe G. Dickinson at the California Institute of Technology. The former is studying especially the influence of the atomic weight or atomic number on the intensity of the reflection, and the latter has been applying the X-ray method to the determination of the structure of substances of somewhat greater crystallographic complexity than most of those previously investigated. Dr. Dickinson has published a research on the structure of wulfenite and scheelite ($PbMoO_4$ and $CaWO_4$), and has carried on an investigation on the structures of sodium chlorate and bromate ($NaClO_3$ and $NaBrO_3$). This work has brought into prominence the great difficulty of locating the atoms whose positions are not determined by the crystallographic symmetry.

It has also shown the necessity of greatly improving the experimental methods of determining the magnitude of the intensities of the reflections. Especial attention is now being given to the perfection of these methods.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. *Continuation of exact investigation of atomic weights and other physico-chemical properties of elements and of simple compounds.* (For previous reports see Year Books Nos. 2–18.)

During the past winter the activity in the Wolcott Gibbs Memorial Laboratory was nearly normal for the first time in four years. Eleven investigations were conducted; many of these brought definite results, while others will be continued in the coming year.

(1) Atomic Weight of Gallium.

Mr. W. M. Craig, having made for the last two years a thorough study of the purification of gallium, proceeded to prepare with great pains and much expenditure of time a larger quantity of this rare element from material from the Bartlesville Zinc Company, Oklahoma. At the close of the academic year he had a number of specimens of the purest gallium chloride hermetically sealed in glass bulbs ready for analysis. There is every reason to believe that the ascertaining of the exact percentage composition of these specimens will give a far better basis for the atomic weight of gallium than any thus far provided.

(2) Atomic Weight of Aluminum.

Dr. Henry Krepelka (on a Government scholarship from Czecho-Slovakia) studied the atomic weight of aluminum by the analysis of pure aluminum bromide. The purest obtainable metal was treated with thoroughly purified bromine vapor and the resulting aluminum bromide was fractionally distilled *in vacuo* with the utmost pains to exclude water or other impurities. Many precautions were taken, the description of which is beyond the scope of this brief report. The final result for the atomic weight of aluminum was 26.963, a value over 0.5 per cent below that previously accepted.

(3) Separation of Lead Isotopes.

The separation of isotopes is at present one of the most insistent problems concerning atomic weights and the periodic system. With the help of Mr. Harold S. King, a careful study of possible methods was undertaken. Lord Rayleigh's mathematical work on diffusion being applied to the case of lead shows that separation by diffusion would be a very slow and almost impossible procedure, at least by ordinary methods. Centrifugal treatment was rejected for the same reason. Among chemical processes the only one for which success has been claimed is the Grignard reaction. A definitive test as to this possibility seemed to be the most immediate need and accordingly the frac-

tional Grignard treatment of various samples of lead has been begun and is being prosecuted systematically. The process has not progressed far enough to settle the question. Mr. King's salary has been paid from another source, but he is employing apparatus belonging to the Carnegie Institution of Washington.

(4) Atomic Weight of Rubidium.

Miss Edith H. Lanman, a graduate student of Radcliffe College, undertook the study of the atomic weight of rubidium with the idea of preparing purer material than has thus far been used and of clearing up a discrepancy in the details of earlier work. She conducted an elaborate series of fractional crystallizations of rubidium dichloriodide, testing spectroscopically the march of impurities. In this way a considerable quantity of very pure rubidium dichloriodide is at hand, almost ready for the determination of the atomic weight next year.

(5) Purification of Gallium by Fractional Crystallization and Effect of Pressure upon the Melting-Point.

Mr. S. Boyer, who had previously tested the purification of gallium by electrolysis as well as by heating in a vacuum, found that one of the best methods of getting rid of small residual traces of impurity was by the fractional crystallization of the metal. In this way he was able to prepare a sample of gallium having a constant melting-point. After all corrections had been applied, this purest specimen was found to melt at 29.752° on the international hydrogen scale. Mr. Boyer then determined the effect of pressure on this melting-point by applying pressure to a quantity of half-melted crystals in a Richards piezometer confined in a steel cylinder (kept at a temperature somewhat below the melting-point) until equilibrium was attained. An increase of 300 megabars pressure was found to cause a lowering of the melting-point of 0.612°. The volume decrease being 3.13 per cent (or 0.00537 c.c. per gram) from the familiar equation of Clapeyron the latent heat of melting is thus found to be 19.04 calories per gram.

(6) Surface Tension of Liquid Gallium.

The work on surface tension mentioned last year was continued by Mr. Boyer with even greater precautions. A special study was made of the size of drop necessary in order to give the true maximum result. The values for mercury and gallium (respectively, 44.06 and 36.55) were essentially equal to those found in the earlier investigation.

(7) Study of Thallium Amalgams.

Mr. Charles P. Smyth continued his study of thallium amalgams containing less than 20 per cent of mercury. He obtained definite evidence that the potential of amalgamated thallium is different from that of pure thallium, due to the formation of a solid solution which contains as much as 12 per cent of mercury. He studied the properties

of this solid solution, measuring not only electromotive forces and heat of further amalgamation, but also hardness and density. These results round out in interesting fashion our data for the complete discussion of the problems presented by thallium amalgams.

(8) Heat of Dilution and Heat Capacity of Sodium Amalgams.

In order to complete the necessary data for the theoretical study of sodium amalgams, begun by Dr. J. B. Conant some years ago and mentioned briefly in the Year Book of the Carnegie Institution of Washington No. 15 (for 1916), page 355, Mr. John Russell, 1851 exhibition scholar from McGill University, investigated carefully, first, the heat of dilution of sodium amalgams, and next, the heat capacity of these interesting binary mixtures. The data make possible an adequate discussion of the thermodynamic behavior of sodium in its solution in mercury, similar to that worked out for thallium with the help of Dr. F. Daniels some time since. It is hoped that this discussion may be ready for publication soon.

(9) Heat of Reaction of Slow Chemical Reactions.

Mr. Oscar C. Bridgeman began an investigation on the heat of reaction of slow chemical changes, such as the hydrolysis of esters. For this purpose he brought together an elaborate apparatus for the automatic regulation of the outer bath of a calorimeter by means of a synthermal regulator functioning through the help of a selenium cell. The work is not yet sufficiently advanced to report quantitative results, but bids fair to yield an interesting outcome next year. Incidental to this work Mr. Bridgeman made a careful comparison of several thermometers used in previous thermo-chemical work with a standardized platinum thermometer, thus putting many earlier thermo-chemical data in position for publication.

(10) Aqueous Vapor-Pressure of Dilute Sulphuric Acid.

With the help of Mr. A. Sprague Coolidge, an extended study of the vapor-pressure of dilute sulphuric acid was begun. The object was to compare this vapor-pressure thermodynamically with that of the aqueous vapor from pure water at various temperatures. The tension of water in sulphuric acid was determined by passing a known volume of air through a peculiar and especially adapted series of saturating towers containing mixtures of sulphuric acid and water of definite concentration. The sulphuric acid was analyzed by a new method dependent upon viscosity, which will receive especial discussion on publication. Investigations were also made as to the departure from the gas-law of rarefied aqueous vapor, together with the extent to which adsorption on the walls of the vessel may vitiate results.

(11) Adsorption of Vapors by Solids.

Dr. Emmett K. Carver (for several years assistant in this laboratory and now Rockefeller Research Fellow) undertook the study of

the problem of adsorption. As a preliminary step, he has developed an apparatus for measuring small pressures which is sensitive to within 0.0003 mm. Although this research does not come under the head of researches primarily subsidized by the Carnegie Institution of Washington, and its main expenses are defrayed from another source, nevertheless the apparatus which he has devised may be of great use in those researches. Moreover, he has been given the temporary use of some instruments belonging to the Carnegie Institution of Washington and therefore this research also, when it is completed, will be in some measure indebted to the Institution for assistance.

A number of papers concerning earlier researches have been published during the year. These will be found listed in the bibliography.

Sherman, H. C., Columbia University, New York, N. Y. *Chemical investigation of amylases and related enzymes.* (For previous reports see Year Books Nos. 11–18.)

During the past 12 months the studies of proteolytic activities of our purified pancreatic amylase preparations and related products referred to in the report for 1918 have been completed, and the investigation of the influence of amino acids upon the activity of amylases, briefly outlined in our report of last year, has been continued.

Two papers relating to purification experiments have been prepared. One of these, dealing chiefly with the proteolytic activities of our pancreatic amylase preparations and related products, has been published in the Journal of the American Chemical Society. The other, describing a more detailed study of certain phases of the purification process, is now in press for publication in the same journal.

Experiments on the influence of aspartic acid and asparagin upon the activities of several amylases, in natural and in purified form, described in outline in our report of last year, were published in the Journal of the American Chemical Society for November 1919, and the study of the effects of amino acids upon the enzymic hydrolysis of starch has now been extended to glycine, alanine, phenylalanine, and tyrosine. In all of these cases the method of experiment has been to allow the enzyme to act for 30 minutes at 40° upon "soluble" starch (prepared by the Lintner method) in the presence of optimum concentrations of sodium chloride and of primary or secondary phosphate, with or without the addition of the amino acid whose influence is to be tested, and then to measure the extent of the enzymic hydrolysis of the starch by determining the amount of reducing sugar which has been formed. This reducing sugar is chiefly maltose; but since small amounts of glucose may also be present, the results are often stated in terms of the weight of cuprous oxide reduced by the sugar or sugars formed. When such amounts of enzyme were used as to result in yields of 200 to 300 mg. of cuprous oxide, the increases (in milligrams) resulting from the

addition of amino acid to the digestion mixture were, in the present series of experiments, as follows:

	Glycine (0.1 p.ct.).	Alanine (0.1 p.ct.).	Phenyl-alanine (0.1 p.ct.).	Tyrosine (0.05 p.ct.).
Commercial pancreatin	18	20	14	23
Purified pancreatic amylase	38	42	36	36
Saliva	26	33	18	30
Malt extract	9	9	6	14
Purified malt amylase	13	16	12	14
Commercial takadiastase	?	11	5	12
Purified amylase of Aspergillus oryzæ	?	15	11	12

The most prominent result of this comparative study is the general similarity of the data obtained for the four amino acids here reported and the two whose effects were discussed in our previous report. Allowing for divergences attributable to experimental error, it appears that the effect of amino acid in facilitating the enzymic hydrolysis of starch is similar, but not necessarily identical, for the different amino acids thus far investigated; that it is somewhat greater for the purified form of the enzyme than for the natural or commercial material in which the enzyme is accompanied by other constituents of the tissue or secretion in question; and that it is greater for the pancreatic and salivary amylases than for the amylases of malt and of *Aspergillus oryzæ*. In general, the addition of a mixture of two amino acids gives practically the same effect as would result from a corresponding concentration of one of them. Such experiments have been made with the following mixtures: aspartic acid and asparagine, aspartic acid and glycine, tyrosine and asparagine, phenylalanine and asparagine, alanine and glycine.

In all of the experiments, either with individual amino acids or with mixtures, the substances to be tested have been neutralized before introducing them into the digestion mixture, and repeated determinations by the electrometric method have demonstrated that the influence of the amino acid or acids upon the enzymic hydrolysis of the starch is not, in our experiments, due to change of hydrogen-ion concentration.

Some progress has been made in the study of the interesting question whether the amino acid literally activates the enzyme or rather protects it from deterioration or inactivation. The very rapid deterioration of water solutions of pancreatic amylase, particularly when highly purified, and the influence of the sodium chloride and secondary phosphate (regularly used to activate this enzyme) in retarding the deterioration have been noted in previous reports. Since the loss of enzymic activity is only retarded and not entirely prevented by the presence of these salts, it seemed not improbable that the favorable

influence of the amino acid may be due, at least in part, to a further protection of the enzyme from deterioration in the aqueous dispersions in which it acts. This we have found to be the case, solutions of pancreatic amylase which had stood for one hour at 40° showing about one-third greater amylase activity when alanine had been added to the solution in advance. The conditions in this case were such as to result in greater deterioration than in our ordinary tests of enzyme activity, both because of longer heating and because of the absence of substrate.

A somewhat extended series of quantitative experiments will be required to determine to just what extent the favorable influence of amino acids upon the activity of amylases is due to protection of these from deterioration. Meantime, the present demonstration that the presence of amino acids does retard deterioration of the enzyme constitutes an interesting addition to the evidence supporting the view that the enzyme itself is a substance of protein nature or which contains protein as an essential constituent.

We have also found that amino acid may be strikingly effective in protecting the enzyme from the deleterious action of an inhibitory agent, such as copper. Thus a pancreatic amylase solution lost 80 per cent of its enzymic activity when copper sulphate was added to the extent of a concentration of 0.00003 molar; but the presence of 0.1 per cent amino acid prevented the inhibition of the enzyme by the copper and resulted in an increase of enzyme activity almost as great as would have been effected by the amino acid in the absence of copper.

In addition to protecting the enzyme from gradual deterioration under the influence of the water in which it is dispersed, or from inhibition by certain actively deleterious substances if present, amino acids may or may not literally activate the enzymic hydrolysis by directly facilitating or accelerating the interaction of enzyme and substrate, or they may function by sustaining the activity of the enzyme through combining with some product or products of the enzyme action, which products might otherwise combine with the enzyme itself, thus reducing its activity, or might if remaining free in the solution tend to bring the hydrolysis to equilibrium. Experiments designed to throw further light upon these points are now in progress.

The efficient work of those who have collaborated in these investigations, whether as research assistants or as volunteers, is gratefully acknowledged. We desire also to thank Dr. Davenport and Dr. Riddle of the Station for Experimental Evolution for the alanine used in our experiments.

ECOLOGY.

Clements, F. E., Tucson, Arizona. *Associate in Ecology.* (For previous reports see Year Books Nos. 16–18.)

As usual, the experimental work of the year has largely been done at the Alpine Laboratory from June 1 to September 15. Further chemical determinations of the amount of rubber in native plants and of the photosynthetic activity of various species have been made at Tucson during the winter and spring. Studies of the regulatory activity of stomata have been carried on at the Desert Laboratory and at the laboratory of the American Smelting and Refining Company in Salt Lake City for the purpose of checking the extensive results already obtained.

Vegetation studies have been made at Tucson during the winter and upon four field expeditions from spring to autumn. The first of these was through Arizona and California, and concerned itself chiefly with the structure and extent of the bunch-grass and coastal sagebrush associations, and with the charting and installing of permanent quadrats. The second traversed southern Arizona, New Mexico, Texas, Oklahoma, Kansas, Nebraska, and eastern Colorado. It dealt chiefly with the desert scrub and desert plains, and with the contact of the latter and the short-grass plains. An exceptional opportunity was afforded for studying the effect of grazing upon the subclimax, mixed and true prairies, and their relation to the short-grass plains. The third expedition was devoted primarily to the study of Bad Lands, and such areas were visited in northeastern Colorado, western Nebraska, western South Dakota, and Wyoming. In addition, the mixed-prairie sagebrush community was examined over a wide area, and its essential nature determined. Especial attention was given to the fauna of the Bad Lands and the mixed-prairie climax. The fourth expedition traversed southern Colorado, northern New Mexico, and central Arizona, chiefly for Bad Lands, but partly also for the study of variation in *Artemisia*, *Chrysothamnus*, and *Atriplex*.

FACTOR STATIONS.

The factor stations at Pike's Peak remain the same as for last year, namely, the plains station in the mixed prairie at 6,000 feet, the base or montane station in Douglas fir at 9,000 feet, and the subalpine station n Engelmann spruce at 11,000 feet. Factor stations were also maintained in the grassland formation at intervals of a difference of 5 inches in the annual rainfall. These were located at Nebraska City and Lincoln (Nebraska), Phillipsburg (Kansas), Burlington and Colorado Springs (Colorado). At Lincoln, substations were also maintained in high and low prairie. In the grassland series, the factors measured were humidity, evaporation, water-content, air and soil temperatures,

while wind and light intensity were also measured in the mountain series, together with rainfall. For determining the variations in light intensity with the altitude, as well as with the season and time of day, a full battery of recording photometers was installed at the three stations for the first time. These employed Azo paper for a record and consequently were checked by hourly readings made by means of the stop-watch photometer on Solio paper, which has now been in use for this purpose for more than twenty years.

The Phytometer Method, by F. E. Clements, J. E. Weaver, and G. W. Goldsmith.

The use of phytometers, or standard plants, to measure habitats in terms of plant response and growth, has now been carried through three summers. The stations, equipment, and species are the same as those employed in 1919, except that photometers have been used to evaluate the light differences. The method of sealing the phytometer cans by means of hard wax melted onto cloth covers was used again with satisfactory results, although the season proved extreme in many ways. An endeavor was made to have the soil and seed as nearly identical as possible with that employed in 1918 and 1919.

The instruments were read each week, soil temperature and water-content determined, and each plant weighed and its water-loss computed. For the sunflowers an empirical formula for obtaining the leaf area from the product of the maximum width and length was worked out, and by its use the leaf area of each plant was computed weekly. The monocotyl leaves were considered as triangles and their weekly area computed on that basis. In addition to leaf area and water-loss, the stem height and diameter were obtained weekly for the sunflowers. For each sealed phytometer a check was grown under identical conditions, except that it lacked the seal. In addition, garbage cans holding about 75 pounds of soil were used both as phytometers and checks. The plants in them were grown through the season to the period of fruiting. These were used partly to determine the time during which normal behavior could be expected from the plants grown in the one-gallon containers.

The first series of phytometers was run from June 9 to July 19. During this time the plains station showed higher average temperature, greater fluctuation between average day and night temperature, less average rainfall, greater average evaporation from atmometers, greater average night but less average day humidity, and greater average wind movement than the other two stations. The subalpine station in general showed conditions opposite to those at the plains station, while the montane base station was usually intermediate.

The sunflowers show a relative increase in height roughly proportional to the elevation, but the stem diameter increases most rapidly at the base station. The leaf area, though slightly greater at

the plains station, increases most rapidly at the base station after the second week. The transpiration per square decimeter varies inversely with the altitude, as is also the case with wheat and oats. In both of the latter the most rapid increase in leaf area was at the base station, and this increase attained its maximum speed only after the second week. In this all three species agree.

The transpiration at the plains station varies roughly per unit of leaf area inversely with the average temperature, evaporation, humidity, and wind in the case of the sunflower, suggesting that light is the paramount factor. With wheat the results are quite different, the water-loss following changes in temperature, humidity, evaporation, and wind. The response with oats is similar but somewhat more complete. At the base station the unit transpiration follows closely the temperature curve and roughly that of evaporation and wind, but shows no relation to the humidity curve. At the subalpine station there is no apparent correlation between the curve of unit transpiration for the sunflower and the curves of average temperature, humidity, and wind, and but a very remote correspondence with average evaporation. With wheat, but especially with oats, the transpiration curve corresponds much more closely with those of temperature and humidity. In dry weight the plains plants run highest, those at the base station are slightly less, while the subalpine plants are but 20 to 30 per cent of those on the plains. The water requirement for sunflower is greatest on the plains, least at the base station, and intermediate at the subalpine one. This is also true for wheat, but it is least for oats at the subalpine station. However, in all cases, the differences at the various stations are small. If based on the green weight, the water requirement decreases in all cases with the altitude, while the succulence increases with the altitude.

Behavior of Stomata, by G. V. Loftfield.

The present series of investigations into the behavior and efficiency of stomata has been concluded during the year and the results summarized. The studies of the year have dealt chiefly with the relation between stomatal movement and transpiration, and partly with the effect of physical factors upon the movement. A new phase of the work has been an inquiry into the effect of stomatal movement upon respiration and gas-exchange. It was found impossible to correlate the transpiration of a plant with its stomatal apertures unchanged with the evaporation from several types of atmometers. This was found to be due to the different nature of the response of plant and instrument to various factors, especially light and heat.

The experiments carried on at Tucson dealt primarily with *Fouquiera splendens* and *Verbena ciliata,* in the hope of explaining the discrepancy in results of other investigators. A satisfactory explanation

of this was found, and the results completely correlated with those obtained at Salt Lake City. In addition, some interesting correlations were obtained between the behavior of the stomata of desert plants and those of mesophytic species grown under similar conditions of aridity.

In addition to extended results dealing with the relation of stomatal opening to physical factors, the following conclusions have been reached:

1. The stomatal movement differs in plants of different ages, and often also in different leaves of the same plant. Moreover, the movements of the stomata of the upper and lower epiderm of the same leaf are markedly different in many plants.

2. Stomatal movement in most plants differs from day to day in more or less close response to physical factors. Stomata are to a considerable degree individual in their response to changing factors, and they act together as a group chiefly because their factor-control is identical.

3. Stomatal movement is but one of several factors affecting transpiration. A plant often shows considerable changes in transpiration because of the factors controlling evaporation, although the stomatal apertures remain the same. Nevertheless, plants of the same species, which have different curves for stomatal opening, also show similar differences in their transpiration curves.

4. Stomatal closure produces a considerable fall in the rate of transpiration, except when evaporation factors counterbalance the effect of closure.

5. Stomata have a definite regulatory action at the time of wilting, and in many plants perhaps only at this time. When the conditions under which a normal mesophyte is growing become more and more arid, the stomata behave more and more like those of such a xerophyte as *Opuntia versicolor*, in which the stomata are closed during the day and open at night.

6. The transpiration of a cut stem can not be compared with that of a potted plant or of one growing naturally, nor can the transpiration of a potted plant be compared with that of a field plant, since the stomatal movement of a cut stem or potted plant is only accidentally the same as in a field plant.

Photosynthetic Efficiency, by F. E. Clements and Frances Long.

The results so far obtained in measuring photosynthetic activity show definite correspondence with the light intensity. This is marked in the crowns of such shrubs as *Acer glabrum*, *Prunus demissa*, and *Rubus deliciosus*. Shade leaves from the center of the crown with a light intensity of 0.04 showed 54 per cent of the photosynthate of leaves in full sun in the case of *Acer* and 55 per cent in the case of *Prunus*. Shade leaves of *Rubus* in a light intensity of 0.006 showed 27 per cent of the amount found in the sun leaves. Several species of herbs showed

a reduction of 50 to 70 per cent of the sun efficiency in the case of ecads growing in shade of 0.04 intensity. As would be expected, there proved to be a wide variation in the amount of photosynthate made by the species of the same shade community, some exhibiting an efficiency 3 to 5 times as great as that of others.

During the present summer attention has been centered upon sun and shade forms of the same species and upon sun and shade leaves of the same shrub or tree. There is some evidence that species which grow normally in the shade have a higher photosynthetic efficiency than the shade ecads of sun species, and this fact has been given especial attention. A large number of samples has been taken on successive days, as well as on the same day to serve as checks. Recording photometers have also been used for the first time to determine the complete curve of light intensity for the day.

Experimental Taxonomy, by F. E. Clements and H. M. Hall.

The total number of transplants now in position is approximately 900. About 70 per cent of the transplants made in 1919 are growing in their new environment and, since 5 plantings are usually made of each form, only 8 species have been lost. The somewhat high mortality was due chiefly to the very unfavorable climatic conditions in California, where the highest percentage of deaths occurred. A new garden has been established at 8,000 feet to accommodate plants brought up from the plains. This comprises 97 beds, about half of which contain species of *Pentstemon*, brought together for the study of variation and competitive pollination. Another garden has been established at 12,000 feet and above timber-line, into which have been transplanted 51 species from middle and lower altitudes. An alpine garden has been started at the plains station, with 30 species represented.

Most of the reciprocals now established have been subjected to the impact of their new environment for only one year, and none of them for more than two years. While it is too early to expect marked results, a change has already taken place in a few instances. These are ecads, the characters of which are easily modified. For example, the sun-form of *Smilacina stellata* has glaucous leaves which are folded longitudinally and make a sharp angle with the stem. In the shade-form, the leaves are flat and horizontally spreading and not glaucous. These have characters that have been used in taxonomic keys for the separation of supposedly distinct species. After plants of the sun-form have been grown in moist shady places for a single season, the leaves are identical with those of the shade-form. Conversely, when transplants are taken from the shade and placed in open sunny spots, the leaves become glaucous, tend to fold longitudinally, and assume an ascending position. These results have been checked by removing the leafy canopy above plants of the shade-form without disturbing the

rootstocks, when the change to the sun-form became complete. In all of these cases, herbarium specimens of the leafy shoots were taken when the transplants were made or before the canopy was removed, and again from the same rootstocks after the change had occurred. These specimens serve for direct comparison and furnish a definite record of the changes produced.

Although some characters are easily modified, others prove to be much less plastic. This applies even to such a variable as stature, at least when this is coupled with other characters. The alpine variety of *Solidago humilis* retains its depressed habit during its first growing season after being transplanted to 8,000 feet, where its reciprocal attains a stature of 1 to 3 feet. Similarly, *Zygadenus alpinus* retains its alpine habit and produces flowers when only 2 to 3 inches high, even when grown alongside of its reciprocal, typical *Z. elegans*, which is 1 to 2 feet tall. It is possible that these alpine forms will become considerably modified under the cumulative effect of the new environment in the course of several years, but there is at present no evident tendency towards such modification.

Taxonomic Monographs, by F. E. Clements and H. M. Hall.

The preparation of detailed monographs of three important genera of North American plants, *Artemisia*, *Chrysothamnus*, and *Atriplex*, is now nearing completion. Field work has been carried on in all of the western States to determine the extent of variation within the species, and the value of the criteria used in their classification. An examination of type-specimens and other authentic material has been made in most of the principal herbaria in the United States, and many forms have been subjected to experimental tests in the gardens on Pike's Peak and at Berkeley. Quantitative methods have been used so far as possible and extensive series of counts and measurements have been made, especially of flowers and fruits. The results have thrown much light upon the value of the criteria commonly used, and in some instances have disclosed important differences. By the use of quantitative and statistical methods, it has been found that great inequality exists between the taxonomic groups heretofore accepted. Many so-called species are based upon fluctuating characters of little value, while other forms are more sharply set off from their neighbors than has been supposed. A new alinement has become necessary to bring the forms into a sequence that expresses their natural relationship.

Phylogeny has been taken as the key-note in the preparation of these monographs and an effort has been made to present the relationships of the numerous forms in a readily intelligible manner. This is done by a series of diagrams so devised that the authors' conception of phylogenetic origin and relationship between any two varieties may be readily seen. The distinctive characters of each taxonomic unit, whether variety, species, or section, are also indicated on the diagram.

To be of real service, any taxonomic treatment must be expressed in a form that can be readily used by a large number of people. The prevalent method of singling out the more striking variations of a group, and describing them as species with little regard to the constancy of their characters, or to their relationships, leads only to confusion. It is certain that a vast majority of people who have occasion to use botanical names are discouraged by the enormous number presented in recent taxonomic treatises. In the present series of monographs special attention has been paid to putting these segregates back into the species to which they belong, though the segregates themselves are recognized when they have varietal rank. By this synthetic method the total number of binomials is greatly reduced, and yet it is with only this smaller number that most botanists and other plant scientists will need to deal. In short, the authors have endeavored to work out a system which will take care of all possible degrees of scientific analysis and at the same time maintain the very essence of taxonomy, namely, evolutionary relationship and classification. While the specialist may divide and subdivide his species as he chooses, the species still remains for the general botanist and scientist, who is concerned only with the major units of a flora or vegetation. Furthermore, it is felt that the analysis of species can not properly be made by the usual method, but that it necessarily involves extensive field and garden study, together with the application of statistical methods.

In addition to the three genera mentioned above, the *Haplopappus* group of the Composites has been given considerable attention and a foundation laid for monographic treatment. This will follow the lines indicated above, but is especially designed to illustrate the treatment of closely related groups, sometimes regarded as distinct genera and sometimes as sections of one inclusive genus.

Taxonomy of the Madieæ, by H. M. Hall.

The Madieæ, or true tarweeds, form a subtribe of the Composites, confined almost exclusively to the Pacific coast of North America, but cultivated to some extent in Europe and elsewhere for their oil and flowers. Because of the attention given to the groups above, it has been impossible to continue the detailed study of these plants. However, the garden cultures assembled at the University of California prior to 1917 have been continued, and field studies have been made as opportunity offered. It is hoped to resume the investigation of the group at an early date, and to give special attention to geographic distribution and its relation to species. The garden experiments will be carried on in an extensive manner for the purpose of throwing light upon the constancy of the taxonomic characters employed.

Statistical Studies, by H. M. Hall.

A beginning has been made in the application of statistical methods to the solution of problems in the taxonomy of the higher plants. In some cases this can best be carried out in the field. Thus, the number of ray-flowers, disk-flowers, and involucral bracts has been determined for 167 heads at two field stations, and these observations are being extended to other species in order to test the constancy with which the number follows some system. Laboratory studies have dealt with the variation in the number of ray-flowers and disk-flowers in several species of *Artemisia* at different stations, as well as the degree of fluctuation at a single station and for an individual plant. Somewhat different is the case of a polymorphous species of *Chrysothamnus*, of which 150 specimens from as many localities were subjected to an examination involving about 1,200 measurements. By this means the variation in the ratio of length of style or appendage to the length of the style-branch and also the ratio between the length of the lobe and the tube of the corolla have been established. Similar studies have been made in a number of other species. The results thus far obtained have been used in determining the degree of constancy of systematic characters and in furnishing evidence of value in ascertaining the relationships of certain forms. It is hoped to extend quantitative methods to all the genera to be monographed, as well as to the experimental study of criteria.

Adaptation and Mutation as a Result of Fire, by F. E. Clements.

As a consequence of fire at the Alpine Laboratory in 1917, the herbaceous layer of the Douglas-fir forest was exposed to the sunlight. This led to the modification of the subdominants into sun-forms, closely approaching adjacent forms commonly regarded as species in some cases and in others producing a new and characteristic sun-form. Chief among the former were *Mertensia pratensis*, modified into a form approaching *M. lanceolata*, and *Erigeron glabellus*, changed to resemble closely *E. macranthus*. In neither case does this amount to identity, but the modification progresses each year under influence of sunlight. Statistical studies have been made of the present stage of adaptation and will be repeated each year as long as the process continues.

The most striking consequence of the fire was the apparent origin by mutation of a new form-genus of grasses. A normal though luxuriant bunch of *Elymus*, which had been under observation earlier, developed 3 to 4 spikelets with long pedicels at each joint, instead of 1 to 2 sessile spikelets. The pedicels were 10 to 15 mm. long in 1918 and widely spreading, giving the appearance of a narrow panicle. In 1920 the lateral spikelets had become short-stalked, while the two central still had long stalks. The spikelets were slender and terete

instead of flattened, and the number of sterile florets much greater than in the normal ones. A statistical study has been made of the various modifications of spikelet and flower, to determine whether the mutant is gradually reverting to the type, as seems to be suggested by one or two inflorescences.

Experimental Pollination, by F. E. Clements and Frances Long.

Studies have been made throughout the summer on the seasonal succession of insect pollinators on the dominants in the region of the Alpine Laboratory. In this connection, quantitative studies have been made of all the visitors to each dominant for extensive periods. This not only shows the range of species visiting each plant, but also the frequence of the visits of each species, the rate of working, the method of work, and the relative efficiency of each pollinator. Thus, in certain species of *Bombus*, it has been found that the drones do about twice as much work as the workers.

Much attention was given to experiments in the competitive relations of flowers to a particular pollinator. Branches or bouquets of one species were placed on a plant of the other in full flower, and vice versa. The competition pairs and groups employed were as follows:

Rubus strigosus: Rubus deliciosus.
Rubus strigosus: Rosa acicularis.
Rubus strigosus, Opulaster opulifolius.
Pentstemon gracilis: Pentstemon glaber.
Pentstemon glaber: Pentstemon glaucus.
Pentstemon glaber: Epilobium spicatum.
Pentstemon glaber: P. barbatus, glaucus, and gracilis.
Aconitum columbianum: Epilobium spicatum.
Aconitum columbianum: Delphinium scopulorum.
Monarda fistulosa: Epilobium spicatum.

With a few exceptions, usually very young or very old bees, even the most conspicuous flower was unable to attract a pollinator from the species it had formed the habit of working on for a particular period, until that species was past its maximum flowering. This was most marked in the case of *Apis mellifica*, but it was also generally true of several species of *Bombus*, *Osmia*, etc.

The use of various manipulation devices was continued. These were chiefly false corollas, painted corollas, removal or mutilation of corolla, change of position, etc. The response to these varied greatly with the kind of flower and insect, and sometimes with the kind of day. *Monarda* furnished a striking instance of the difference between individuals in behavior and of the fixity of habit in certain individuals. In one large group, *Bombus proximus* and *B. bifarius* were robbing the flowers by boring a hole at the base of the corolla tube, while in a smaller patch a few yards away they were working hard to reach the nectar through the throat. When the corolla tubes were cut short in flowers of the first group, both species continued to rob, though they could easily reach the nectar through the tube.

Climax Formations, by F. E. Clements.

Continued study of the great formations and associations of the West further emphasizes the basic nature of the classification that rests upon development. This is true not only of the associations, but also of the relation of formations to each other. Furthermore, the opportunity to see a large number of associations each year in the complete range of climatic and soil conditions affords results which are highly objective and quasi-experimental in nature. This opportunity has been greatly enhanced during the past four years by the variation in rainfall, which has run the gamut from the severest drought to the maximum rainfall known.

While nearly all the climax formations have again been traversed, those that have received extensive study are the grassland, sagebrush, and desert scrub. The bunch-grass prairie was studied from northeastern Oregon through southern California, and much additional evidence secured of its former extent and dominance. While the northern *Agropyrum* and the southern *Stipa* areas seem almost distinct to-day, these two dominants were found much mixed in southern Oregon and northern California, and there is little question that they were once found together over much wider areas. The area of the bunch-grass prairie has been extended to the edge of the Mohave Desert, and it now appears highly probable that the latter was grassland from the Miocene through the Pleistocene.

Of equally great interest was the discovery of the extent and importance of the Coastal sagebrush association. This proves to be one of the major communities of the southern half of California, occurring nearly everywhere on the Coast Range and cross-ranges between the grassland and the true chaparral. It occupies a considerable portion of the western edge of the Mohave Desert and of Antelope Valley, where it becomes mixed with the desert scrub, especially *Larrea*. In the Mohave Desert, *Artemisia tridentata* is a constant member, while about Saugus and Newhall this is replaced by *A. t. parishii*. Both of these dominants confirm the relationship of the coastal association to the true sagebrush of the Great Basin. Tracing this community over nearly a thousand miles revealed a number of additional dominants, chief among them *Pentstemon antirrhinoides*, *Eriodictyum tomentosum*, *Isomeris arborea*, *Rhamnus integrifolia* and *ovata*, and *Salvia carnosa*.

Observations in the Mohave and Colorado Deserts threw additional light upon the structure and successful relations of the desert scrub. They confirmed the inclusion of a number of apparently subclimax dominants in the formation, in spite of a marked tendency to become dominant on bajadas and valley plains, where *Larrea* is often absent. This was notably true of *Fouquiera* and *Cereus giganteus*, which were found in the Colorado Desert and Gila Valley in association with *Larrea*, many miles from the bajadas of which they are so charac-

teristic. Similar results were obtained for the eastern desert scrub in New Mexico and its ecotone with the grassland was traced through a new region.

The short-grass plains, subclimax prairie, true prairie, and mixed prairie were given much detailed attention in eastern New Mexico, Oklahoma, Kansas, Nebraska, Colorado, South Dakota, and Wyoming. The most important results, however, relate to the effect of grazing and are considered later. The occurrence of true prairie on the "breaks" of the Canadian River and of "shinry," a mixed community of dwarf oak and *Andropogon*, was significant of the associational relations in the short-grass region. Nearly the whole length of the contact between mixed prairie and sagebrush in Wyoming was traced in some detail. While this broad ecotone often takes its color and appearance from the sagebrush, the latter rarely occupies half the ground, except in valleys or on new slopes.

Changes in Vegetation, by F. E. Clements and E. S. Clements.

During the past eight years the conviction has steadily grown that nearly all grassland has been greatly and some grassland profoundly modified by animals. The effect of grazing has often been markedly supplemented by the dry phase of the climatic cycle. The universal importance of grazing as a primary factor in the structure of grassland has now been confirmed beyond any question. The evidence is too lengthy to be reviewed here and will be treated in a special paper. Perhaps the most striking evidence has been obtained from Sheep Mountain, an isolated butte with precipitous walls and a grassy top 40 to 50 square miles in extent. The larger third of this is regularly grazed by cattle, with the result that the short-grasses are dominant and the tall-grasses secondary, having been greatly reduced in the past five years. The middle area is connected with the preceding by a narrow land-bridge which has permitted horses but not cattle to pass. This area seems to have been grazed only by horses a number of years ago. The tall-grasses, with much *Stipa*, are dominant, while the short-grasses form a carpet over about a third of the surface. The third area is completely cut off from the second by a deep bad-land gorge, and all the evidence indicates that it has never been grazed. Here the tall-grasses are in full control, with *Stipa* dominant, and only occasional culms of *Bouteloua gracilis* or tufts of *Carex filifolia*.

The most completely modified of all the grassland associations is the bunch-grass prairie of California. In fact, until the present investigations were begun, the grass community that preceded and yielded to the exotic *Avena*, *Hordeum*, *Bromus*, and *Festuca* was not at all known. The studies of the past four years have pieced together the original *Stipa* prairie, until its general outlines can be traced throughout the State by means of innumerable relict communities. Some of these

still occupy areas of several square miles and serve to give a fairly complete picture of the original community. In wide stretches of the Great Interior Valley, such as the vast Bakersfield plain, where overgrazing was most serious, it was at first thought that *Stipa* had completely disappeared. A careful search during the past spring revealed relict bunches and groups wherever there was some protection, while the region about Tehachipi Pass showed it as a dominant still. This is in accord with the statement of Fremont, who speaks of this as a bunch-grass country.

The question of the disappearance of the buffalo grass and the incoming of the bluestems has been dealt with in "Plant Succession," and it will suffice to point out here that this was purely an effect of grazing. Much more important is the question of the effect of grazing on mixed prairie which contains both tall-grasses and short-grasses. The fact that pastures in the mixed-prairie associations were characterized chiefly or wholly by short-grasses was first noted in 1916. Since that time hundreds of observations have been made of the fact that grazing reduces or drives out the tall-grasses completely, while it correspondingly favors the short-grasses. *Stipa* is handicapped more than *Agropyrum* or *Andropogon;* hence, it disappears first, and consequently is the best indicator of the initial degrees of overgrazing. *Bulbilis* has the advantage of *Bouteloua*, by virtue of its much denser mat and its stolons, so that it is gradually increasing wherever present. A particular search has been made for tall-grasses in supposedly short-grass regions during this spring. The results seem to leave no doubt that there is no original short-grass north of the thirty-ninth parallel at least, and that the extensive short-grass areas in this region are all due to overgrazing, chiefly during the period when eastern Colorado, for example, was a great lane for Texas cattle driven to Montana for summer range. The short-grass of northeastern New Mexico is also derived from mixed prairie, but whether this is true of the Staked Plains and of northern Arizona is not yet determined.

Where grassland touches sagebrush or scrub, grazing alone favors the shrubs, though if fire enters regularly this advantage is more than offset, and the grasses encroach upon the scrub. All around the northern and eastern edges of the great sagebrush mass, grazing has reduced or destroyed the hold of the grasses and permitted the steady advance of sagebrush. This is particularly true in Oregon and Idaho, where extensive areas appear to be climax sagebrush, and their true character is only to be gained by a study of the grass relicts (Merriam, Univ. Cal. Chron., 1899). Along the eastern edge of the sagebrush association in Wyoming and Montana, the greater rainfall has enabled the mixed prairie to hold its own in a large measure and to adopt the low sagebrushes into the community as shrubby societies. Thus, the broad ecotone of prairie and sagebrush in central Wyoming is really produced

by grazing and is controlled only secondarily by climate. This is similarly true of the great mesquite savannahs which occur from central Texas to western Arizona. While their origin is possible in the first place because of wet phases of the climatic cycle, their spread and persistence is due to overgrazing.

Natural Parks, by F. E. Clements and E. S. Clements.

During the summers of 1909 and 1910, a comprehensive survey was made of the natural parks of Colorado, with especial reference to their causes and origin. This problem has again been taken up in the last few years in other mountain regions. These results agree completely with those obtained earlier, and the findings are now being brought together. For the most part, natural parks are grassland areas of a half-mile to several miles in extent, surrounded by forest or woodland. Sometimes this term is also applied to savannah, in which the trees are merely scattered in the grassland. The grassland concerned is usually subclimax meadow, found in the montane and subalpine zones, though it may be an association of the grassland formation, especially in the case of yellow pine or lodge-pole pine parks. The best parks studied are those formed by Engelmann spruce and alpine fir, and by lodge-pole pine, though yellow pine is sometimes a good second. All trees at the upper or lower tree limit, such as foxtail pine, pinyon, aspen, etc., may form parks, but these are less common and less characteristic. Moreover, while all natural parks in the usual sense are carpeted with grass, it is difficult to distinguish these from parks containing sagebrush or scrub.

All natural parks are consequences of succession. The forest mass or edge is the climax, or sometimes the subclimax, as in the case of lodge-pole pine. The grass center, or the scrub center, is the stage preceding as a rule. Probably the greatest number of natural parks are due to fire, a secondary succession developing on the burned area and persisting for a long time in the subclimax or grass stage. This grass cover may persist for several hundred years or longer, largely owing to the advantage the grasses have in competition with the tree seedlings. The fine parks in the subalpine forest of the Uncompahgre Plateau in southwestern Colorado and those of lodge-pole pine in the Big Horn Mountains of Wyoming are burn parks. A very large number of parks also arise as a consequence of primary succession in lakes and ponds. These are very frequent, but usually of much smaller extent. A great many of them remain for a long time in the sedge-swamp stage and hence do not appear to be parks at all. The most striking parks of this type are those which have given their name to three great intermountain regions in Colorado, namely, South Park, Middle Park, and North Park. These are so extensive that all stages of primary succession occur in them, though by far the greatest area is covered with

grasses or with sedges and rushes. Another remarkable type of park is due to the xerophytic succession on long rock ridges. Probably the most unique park of this sort occupies the Black Hills rim, the two parallel ridges being covered with yellow pine and the intervening valley with luxuriant mixed prairie. Similar though less extensive parks are found in the Black Forest, which stretches eastward from Pike's Peak over the watershed of the Arkansas and Platte Rivers.

Periodicity in Vegetation, by F. E. Clements, E. S. Clements, and G. V. Loftfield.

Several kinds of periodicity in vegetation have been studied during the past three years. The simplest and most common of these is the response of grassland to the wet and dry phases of the climatic cycle. By a remarkable chance, the two or three years of exceptional drought were followed generally by a year of the greatest rainfall known over much of the West. These extremes were faithfully reflected in the grasses and their associated herbs. One of the poorest years known for grassland was followed immediately or a year later by the best year, with the result that it was possible to make exact comparisons of the two extreme conditions. This juxtaposition of extremes was so graphic that it revealed many facts that might have remained obscure in the more orderly progress of the climatic and vegetational cycles. This was probably especially true in giving greater prominence to relict groups and areas, and hence every advantage has been taken of this opportunity to trace vegetational changes. A similar periodicity has occurred in the case of shrubs and trees, but it is readily seen only in the case of seedlings.

Even a more striking type of periodic behavior has been shown by the winter annuals of the desert plains of southern Arizona. The very dry summer of 1918 was followed by normal winter rainfall, with the result that the winter annuals developed in great luxuriance. This was especially true of *Eschscholtzia mexicana*, the poppy. This was so dominant over many square miles on and around the Santa Rita Range Reserve that the brilliant mass could be seen 50 miles away. Two other annuals, *Lupinus sparsiflorus* and *Malacothrix sonchoides*, were frequent, but of minor importance. The next summer and winter were wet, and it was expected that the innumerable seeds of the poppy would result in a greater crop than the year before. It was a great surprise, in consequence, to find that the poppy was of little or no importance over the plain, which was covered by alternes of *Gilia aurea*, *Franseria*, and *Orthocarpus*, and other less abundant herbs. The poppies retained their dominance only on the many bare mounds formed by kangaroo rats. This furnished the plausible clue that the grassy plain received too little heat at the time water-content was at its best, and hence the poppy seeds germinated only on the warmer mounds. Quadrats have been installed each year in the areas of

typical dominance, and it is expected that these will aid in the solution of the rhythm.

A third type of periodicity occurs in the case of such secondary species as *Calypso borealis* and *Botrychium lunularia*. Ten years ago these plants were so rare in the vicinity of the Alpine Laboratory as to be known by actual count. The present summer they are a hundred times more abundant. The cause for this is obscure, though it probably is related to the greater rainfall of the past three years, as Pike's Peak has passed through the drought period of 1917–1919 with more than the normal rainfall. Quadrats have been installed in these communities and their behavior will be followed in detail.

The fourth type of periodicity involves the life-form of certain grasses and herbs in the desert plains. During dry periods there is a marked increase in the annual forms. *Bouteloua rothrockii* appears to turn into the annual *B. polystachya*, and the perennial *Franseria tenuifolia* becomes annual, and thus through a number of species. With the return of wet years the perennial forms predominate.

Transplant Quadrats and Areas, by F. E. Clements and J. E. Weaver.

Studies in the application of the methods and principles of experimental vegetation by the establishment of transplant and seeded quadrats were begun in 1918 and greatly extended during 1919. During the past season they have been continued on a very extensive scale. In addition to the former stations at Lincoln (Nebraska) and Colorado Springs, other permanent stations have been established at Nebraska City, Phillipsburg (Kansas), and Burlington (Colorado). These stations are equipped with instruments for the determination of air and soil temperatures, humidity, and evaporation, while determinations of water-content are made to a depth of 4 feet.

Dominants are transplanted by cutting out and removing blocks of soil, 12 to 18 inches square and about 8 inches deep, and inserting these blocks in areas of similar dimensions excavated in the new habitat. This is usually done in duplicate, the soil being carefully compacted about the sides of the transplants and at least one series watered until established, as well as at critical periods throughout the first growing-season. In this manner reciprocal transplants of the following dominants have been made at Lincoln in high and low prairie, gravel-knoll, wet meadow, and salt flat: *Agropyrum spicatum, Andropogon furcatus, A. nutans, A. scoparius, Bouteloua gracilis, B. curtipendula, Bulbilis dactyloides, Distichlis spicata, Elymus canadensis, Kœleria cristata, Panicum virgatum, Poa pratensis, Spartina cynosuroides*, and *Stipa spartea*. Practically all of these have been transplanted into the short-grass area at Burlington and the mixed prairie at Colorado Springs. Several of them have likewise been planted in the desert plains at Sonora, Texas, and Tucson, Arizona, and in the montane zone at the Alpine Laboratory. Transplants of *Stipa setigera* and

S. eminens from Berkeley, California, and of several species of *Aristida* and *Bouteloua* from Tucson, have been made at Lincoln, together with their reciprocals.

Most of the preceding species, together with *Aristida purpurea, Bouteloua hirsuta, Stipa comata, S. viridula*, and *Liatris punctata*, have been seeded at the five permanent stations. This has been done in three different ways in order to permit an exact analysis of the results. In the first method, the seed was sown on the surface and only slightly covered with débris, thus simulating conditions in nature and subjecting the seedlings to both root and shoot competition from existing vegetation. In the second, seed was sown at the proper depth in a trench 3 or 4 inches wide, from which the sod had been removed to a depth of 4 inches and the soil replaced in a mellow condition. This made germination more certain and did away with root competition until the seedlings were established, but did not seriously modify aerial conditions. In the third method, areas 0.5 meter square were denuded to a depth of 3 or 4 inches and the sod replaced by fine soil in which the seed was planted. Seedlings were also grown in adjacent tilled areas, primarily for the purpose of studying root development.

The season has been very favorable for plant growth, but considerable mortality among seedlings, even during short periods of drought, emphasized the difficulties of ecesis and showed strikingly the effect of environment and competition in selecting the plant populations in the several habitats. While the unusual moisture greatly favored the growth of the transplants in the salt flats, it resulted in the lack of sufficient aeration for the growth of many transplants in the wet meadow. Certain species prove able to grow but not to reproduce in their new habitat; others are being replaced by the invasion of former dominants, while differences between the plants in the original and the new habitat are indicated by the various degrees of growth and reproduction.

To obtain the fullest results from these studies, such as the comparative equivalence of dominants of different associations, the conditions under which extral dominants are adopted into the association, and the outcome between dominants and subdominants, and between subdominants alone, it is planned to continue the studies through a series of years. However, the results already obtained serve to indicate the relative importance of migration, physical factors, competition, and biotic influences, such as grazing animals, rodents, etc., in affecting the invasion of dominants and the permanence of communities. It seems certain that the use of transplant and seed areas must come to be regarded as indispensable for adequate and objective vegetation studies. The indicator value of such work is obvious, and it is being increased by correlating it not only with native plant production, but also with the production of crop plants.

Crop Development and Production Studies, by F. E. Clements and J. E. Weaver.

The development and production of certain crop plants have been studied at the stations at Lincoln, Phillipsburg, and Burlington in connection with the preceding studies. White Kherson oats, Marquis spring wheat, barley, alfalfa, white sweet clover, and sunflowers were used. Areas typically representative of soil and topography at each station were selected, the seed-bed properly prepared, and the cereals and legumes sown at the same rate (that determined by the farm practice for central Kansas). This was done at the usual time of seeding, on an area approximately one-thirtieth of an acre at the several stations. These areas joined those of native vegetation, where complete records of precipitation, humidity, evaporation, soil, and air temperatures were obtained. Water-content readings to a depth of 4 feet were made at frequent intervals among the crop plants. Careful records of the root and shoot development of all the crops were made at each station at regular intervals. For oats and wheat, and in part for alfalfa and sweet clover, drawings of root and shoot development were made to scale in the field at Lincoln, thus giving several stages in the sequence from seedling to mature plant.

When ripe, the cereals were harvested by selecting 25 to 30 meter-quadrats of each species, from each planting, and by cutting the grain near the surface of the soil. The plants from each quadrat were tied in a separate bundle, and all were shipped to the botanical laboratories of the University of Nebraska, where they were thoroughly air-dried and finally weighed. At two or three intervals throughout the season, 300 to 500 average plants of alfalfa and sweet clover were measured, cut, dried in the laboratory, and finally weighed. Similar data were obtained for sunflowers. In general, climatic conditions for plant growth were unusually favorable, especially at Phillipsburg and Burlington. The correlation of crop production with native vegetation was least at Burlington and usually greatest at Lincoln, although certain cuttings of sunflowers and legumes at Phillipsburg closely approached or even exceeded the yield at Lincoln.

Plant Production Quadrats, by J. E. Weaver.

A study of the effect of climate upon the production of natural vegetation has been made at several stations through the grassland formation. These are Nebraska City in the subclimax prairie, Lincoln in the true prairie, Phillipsburg in the mixed prairie, and Burlington in the short-grass plains. This series of stations gives a range of annual precipitation from about 33 inches at Nebraska City to 28 at Lincoln, 23 at Phillipsburg, and 17 at Burlington. The method employed was to select 20 to 30 meter-quadrats in typical undisturbed areas in the climax vegetation. The height and density of the vegetation, the abundance of dominant and subdominant species, etc., are recorded, and pho-

tographs are made of representative quadrats. The vegetation is then removed by cutting near the surface of the soil, after which it is collected, thoroughly dried, and the plant production determined on the basis of dry weight. Thus the relative growth of vegetation as a unit, as well as the comparative importance of the dominants in the various associations, is determined. The method is further useful for determining the effects of mowing at different seasons, of grazing, and of other disturbances. The results thus far obtained indicate a rather direct correlation between available water-content and plant production, but it is hoped to continue the studies throughout the climatic cycle in order to secure a total range of correlation.

Root Development and Absorption, by J. E. Weaver.

In connection with the root development of crop plants, a series of experiments on barley was made to determine the degree of absorption at different levels throughout the period of growth. Cylindrical sheet-metal containers, 18 inches in diameter and about 42 inches deep, were placed in trenches in the soil near the crop plots at Lincoln in such a manner that the plants in them grew under fairly normal field conditions. These containers were filled with soil and subsoil taken from the trench. The soil from each 6-inch level was kept separate, thoroughly mixed to insure uniform texture and water-content, and then placed in the containers (16 in number) in such manner that when compacted the soil of the containers was very similar to that surrounding them on the outside. A wax seal, consisting of 85 per cent paraffin and 15 per cent petrolatum, was melted and poured upon the soil quite hot in order to separate the soil in a number of containers into layers 6 inches deep, with a known water-content. The efficiency of the seal in preventing water movement was tested by numerous check containers. The ease with which the roots of crop plants penetrated the seal was shown both by their distribution in the soil mass and their normal development when compared with plants grown in unsealed containers and in experimental plots. The first seal was inserted at a depth of 6 inches. The plants were permitted to grow thickly in rows through a slit 1 inch wide and 18 inches long, through the sloping wooden roof of the container. By this method it is possible to remove the containers for root examination and soil-moisture readings from time to time, and to determine the actively absorbing areas of the roots at any period in the development of the plant. The method lends itself readily also to the study of root development in soil layers of different texture, different water-content or air-content, and likewise to experiments in soil fertility.

Climatic Cycles, by F. E. Clements and A. E. Douglass.

In further studies of the correlation between climatic cycles and tree-growth, a standard curve has been constructed for *Sequoia*, reaching

back 3,300 years. This is intended not merely as a standard to which all *Sequoia* curves may be referred, but also as a basis for checking and cross-identifying the results from trees of adjacent regions. Much progress has been made in the improvement of the periodograph, and it will be soon available for much readier and more accurate analysis of both old and new curves. The annual rings of cores taken from the pueblo ruins at Aztec, New Mexico, have been studied with special reference to the possibility of dating the ruins and obtaining the relative age of the different portions. It has been possible to do this, and it is hoped that the method of cross-identification will yield the dates of the actual construction. A considerable number of cores have been obtained from several species at the Alpine Laboratory with the object of determining the effect of slope-exposure on the growth of annual rings. A journey has been made to the Miocene fossil forests of Florissant and Yellowstone Park and to the Eocene forests at Medora, North Dakota, for the purpose of studying the rings of the fossil trees in relation to climatic cycles of the past. Since complete sections are practically impossible, it is hoped to construct such in so far as possible by means of photographs, tracings, and fragments.

An extensive study has been made of the relation of drought periods to climatic cycles throughout the West. In addition to the 17 western States, an analysis has been made of the weather records of Indiana, Illinois, Wisconsin, Minnesota, Iowa, and Missouri. The annual excess or deficit in rainfall has been tabulated for each State for 8 periods of 5 years each, centering on the sun-spot maxima of 1837, 1848, 1860, 1870, 1883, 1893, 1907, and 1917. The results show not only that every State has had from 2 to 4 years of critical drought at the most intense sun-spot maxima, but this is also fully disclosed in the totals for the entire region. For purposes of comparison, a study is likewise being made of the relation between sun-spot maxima and rainfall in other arid regions, such as Argentina and South Africa.

Permanent Quadrats, by F. E. Clements, E. S. Clements, and G. V. Loftfield.

The use of permanent quadrats for the study of changes in vegetation and of the competition of dominants and of subdominants has now been extended to the majority of the plant associations of the West. The total number is about 200. In connection with the transplant areas, they are used to follow the course of ecesis in detail, as well as for determining the total production in native as well as culture vegetation. Such clip quadrats have also been employed in connection with the rodent exclosures in Arizona. Quadrats have also been established for the purpose of tracing periodicity in vegetation, and they are especially important in following the alternation of annual-perennip species where the identity of each individual must be beyond question. A new type of permanent quadrat has been established in the basic quad-

rat-transect which runs for more than a half mile through the various communities at the Alpine Laboratory. This is a soil quadrat 4 decimeters square, in layers of 2.5 cm., until a depth is reached at which no organisms occur. Such a quadrat is primarily for the study of animal organisms, as shown in the next section, but it serves also for the determination of algæ and fungi in the soil.

In successional studies, the tendency is increasingly to group quadrats in a transect running through the series of zones or communities. This permits the installation of quadrats in representative areas as well as the mapping of community limits. A new method of photographing permanent areas and quadrats has been devised in which three stakes are set in the ground in such manner as to record the exact position of the tripod for future exposures. This method has also been employed for recording the exact position of a group or community for tracing the course of competition in grassland. A tilting tripod top has been employed for taking views directly above plants and nests, and it is hoped to develop this for the purpose of taking overhead views of quadrats of many kinds, in lieu of charting them. Various improvements have been made in the manner of staking quadrats, new tapes have been devised, and a larger form of chart has been developed to permit greater minuteness of detail.

Soil Fauna of Engelmann Canyon, by G. W. Goldsmith.

A qualitative and quantitative study is being made at points across Engelmann Canyon to determine the relation of the fauna to soil conditions and plant cover, and the biotic correlations. At the place chosen for the work, the canyon runs approximately east and west, the walls being about 500 feet high. Since a careful survey of the vegetation has already been made by means of a transect, and the elevations and distances accurately mapped, all the soil quadrats are located in this transect. A soil quadrat, 2 dm. square, is located in each typical community and the soil to a depth of 2.5 cm. is quickly removed and placed in a waxed paper-bag. The soil is then removed successively from similar layers to a depth of 2 dm. and the whole brought at once to the laboratory for examination. At the time of each collection, the temperature of the air immediately above the soil, and of the soil at 2.5 cm. and 2 dm. was taken. Samples of the layers were also taken in duplicate and used for determining the water-content and ignition-loss as well as for mechanical analysis. The bagged material is carefully sifted through a screen with 6 meshes per inch and then through a second screen with 14 meshes per inch. After each sifting it is spread in a thin layer over a white oilcloth and kept for several minutes under close observation. The animals found are collected by means of the forceps and a brush saturated with glycerine, and are placed in 50 per cent alcohol. When no more animals are visible,

the soil is placed in an apparatus similar to that devised by Moczarski (described by Holdhous, 1910). All the animals removed from the soil by this means are added to those removed after sifting in order to obtain the total.

Nearly all the animal life in the soil studied is limited to the first 2.5 cm. This is true of the different communities and shows no precise correlation with temperature, moisture, fineness, or ignition-loss. In the yellow pine-bearberry community the bare gravel contains *Acarina* in comparatively small numbers, but the duff covered with bearberry contains an abundance of *Collembola*, as well as mites. At the other extreme, the wet fine silt along the brook bank is rich in earthworms and insects, both larvæ and adults, in addition to numerous *Acarina* and *Collembola*, while the soil of the fir forest contains large numbers of mites, *Collembola*, *Chilapoda*, *Diplopoda*, *Pseudoscorpions*, and insects, together with occasional earthworms. The other quadrat stations are more or less intermediate between those given. The seasonal changes in the species and the number of individuals are being followed in detail. The particular factors involved in the control of various species are being determined by removing species peculiar to one area to other quadrats and keeping them under observation in screen vivaria.

Faunal Studies in Mixed Prairie and Bad Lands, by F. E. Clements and C. T. Vorhies.

A special study has been made throughout the Bad Land expedition of the fauna of the mixed-prairie climax and the characteristic Bad Lands in it. The Bad Lands afford a bewildering number of successional stages and thus permit ready comparison with the fauna of the biotic climax. Some attention was paid to practically all the animal groups, but the study was concentrated upon mammals, birds, and insects. A list of species found was made for each region and for each Bad Land locality, and some account was taken of their relative abundance. It was recognized that, in a single climax association at least, the basic control of the animal population must be exerted by the plants, and hence the chief study was devoted to the correlations involving food, shelter, cover, and materials. Among the insects, many oligotropic and monotropic forms were found, but the birds and mammals were able to adapt themselves more easily to changing vegetation. This ability was found to be most marked in the prairie-dog, especially *Cynomys leucurus*, which was found almost equally at home in a pure consocies of *Atriplex nuttallii*, in sagebrush, in mixed sagebrush and prairie, and in various communities of the mixed prairie. A study of special interest dealt with the material used by ground birds for the different portions of their nests. In all cases this was found to be determined by the nature of the community and by the season, as would

be expected, though in each case a skillful choice was made of the materials available.

Biotic Succession in Bad Lands, by F. E. Clements.

The Bad Lands of the West have been actively studied since 1913. More than sixty localities have been visited, many of them several times. During the present summer, the Oligocene Bad Lands of Nebraska and South Dakota have been revisited, as well as the Permian and Triassic Bad Lands of the Petrified Forest and the Painted Desert, and the Cretaceous ones of southwestern Colorado and adjacent New Mexico. The Wasatch exposures at Tatman Mountain were seen for the first time, as were the Wind River ones from Shoshoni eastward, and the Lance from Gillette to Clearmont. The characteristic Red Beds of the Spearfish and Chugwater formations were again studied around the Black Hills and in central Wyoming. Finally, the Eocene Bad Lands of the Puerco, Torrejon, and Wasatch formations of the San Juan Basin in northern New Mexico were also visited for the first time.

Bad Lands are found in several climax associations of the West, notably the mixed prairie, short-grass, bunch-grass, sagebrush, and desert scrub. As areas of rapid erosion, they offer exceptional opportunities for the study of biotic succession at the present day, as evidenced by the succession of plant communities. These are determined by intensely xerophytic conditions as to soil, since the latter is uniformly clay or a sandy clay. The climate is semiarid in the mixed prairie and arid for all the other climaxes. The development of vegetation in the eroded valley plains produces stable conditions, each marked by the climax, in which new erosion occurs. In the Oligocene Bad Lands as many as five such erosion levels are found. The relative age of these is readily determined by taking advantage of the fact that the woody undershrubs of the valley plain stand above the surface of the soil. The rate of erosion is found by dividing the height of the short stem by the number of annual rings in it.

The Bad Lands have been taken as the basis of an endeavor to organize the field of paleo-ecology in some detail. Since the deposits in which they occur stretch from the Permian to the Pleistocene, they afford an almost complete picture of the rise to dominance of the great angiospermous flora and the great mammalian fauna. In addition, the nature and structure of their deposits furnish abundant evidence of the climate and topography at the time of deposition. These bear a more or less direct relation to conditions on the upland, and through them it is hoped to obtain a more complete picture of upland climate and vegetation, especially with respect to climatic cycles. In this connection, measurements have been made of depositional layers of all kinds in several formations, and it is hoped to extend this to many

more. Complete tabulations have been made of the flora and fauna of each formation and epoch, and these are being organized into climax and successional communities on the basis of the system set forth in "Plant Succession." The results already secured seem to assure the discovery of a number of new correlations between the climate, vegetation, and fauna of the past.

Indicator Plants, by F. E. Clements.

While some attention has been given to practically all types of indicators, it has been centered chiefly upon those that have to do with climate, grazing, seral sequence, and competition. A striking instance of the value of subdominants as climatic indicators was found in the Red Beds valley inside the Black Hills rim. The societies of the mixed prairie were developed here to a marked degree, equaled only in the true prairies far to the east, and they furnished a decisive indication of greater rainfall and reduced evaporation. It was also clearly recognized for the first time that the presence of *Amorpha*, *Rosa*, *Ceanothus*, and other bushes indicated a marked tendency toward a woodland climate. The indicator value of these plants has been obscured by grazing and mowing, and was first clearly revealed in protected places, where *Amorpha* in particular grew 5 or 6 feet high.

The most detailed indicator studies have dealt with the response of the various grassland dominants and subdominants to grazing. Each species has its particular response, which is often largely characteristic of the genus as well. This is best shown in the case of *Stipa*, the climax species of which bear essentially the same relation to overgrazing. They are the first dominants to disappear, whether it be *Stipa setigera* and *eminens* in the bunch-grass prairie, *Stipa comata* and *pennata* in the mixed prairie, or *Stipa spartea* in the true prairie. This is chiefly due to their early start in the spring, as a result of which they must stand the brunt of early grazing, and partly also to the absence of vigorous rootstocks or stolons. The same causes explain the fact that *Kœleria cristata* usually disappears next, and hence indicates a somewhat greater degree of overgrazing. *Agropyrum glaucum* is much more persistent by virtue of its remarkable rootstocks, and it is often abundant where both *Stipa* and *Kœleria* have vanished. It is a tall-grass, however, and overgrazing handicaps it in comparison with the short-grasses because of the much greater consumption of its leaves. Its disappearance marks the destruction of the most valuable of all forage types, the mixed prairie, and the final dominance of short-grass. Still more serious overgrazing is indicated by the gradual destruction of the open mats of *Bouteloua gracilis*, which is much more easily trampled out than *Carex filifolia* or *Bulbilis dactyloides*. When both are present, *Carex* next succumbs and *Bulbilis* alone persists by virtue of its dense mat and vigorous stolons.

This condition is rare except in pastures, where overgrazing reaches its extreme.

A basic discovery has been made to the effect that all dominants and subdominants in a group are indicators of competition with each other to varying degrees. Under optimum conditions, with competition lacking, it has been found that the dominant grasses of the true and mixed prairie will grow to heights two and even three times greater than the usual height in the community. Thus, in areas of similar water-content or regions of the same rainfall, height and spread may be used as fairly exact indicators of the degree of competition.

Grazing Research, by F. E. Clements, Edith Clements, and G. V. Loftfield.

Grazing research has been continued throughout the year, and informal cooperation has been entered into with several additional State experiment stations. The generally abundant rains over the Great Plains and the Southwest produced an exceptional development of grass and permitted a close comparison with grazing conditions in the two preceding years of drought. The abundance of grass forage reacted upon the herbaceous population more or less favorably, as the herbs were less grazed and increased correspondingly. The fenced inclosures on the Santa Rita Range Reserve showed less striking differences than were expected, and clearly demonstrated the remarkable capacity of grasses to recover after severe drought. It is assumed that the explanation of this is to be found in the storage in rootstock or crown, and this possibility is being studied.

The grass quadrats of the inclosures were charted in the fall, and those of winter annuals in the spring. Some quadrats are used to study the relation between the two, and these were charted at both times. The grass quadrats in rodent-infested areas in northern Arizona were charted in the fall. At this time the grasses showed the most striking differences under protection, and these differences were measured and photographed.

Land Classification and Settlement, by F. E. Clements and E. S. Clements.

Further studies have been made of the causes underlying the abandonment of farms and ranches over the Great Plains and in the Southwest. These abandoned farms are more numerous than for a long time, in consequence of the critical droughts of 1916–1918. Since the dry years of 1907 and 1908 there had been extensive settlement in the arid regions of the West, stimulated first by the enlargement of the homestead to 320 and then recently to 640 acres. These enlarged homesteads did not increase the certainty of producing crops, except in so far as they permitted successful dry-farming, and they were still quite too small to make stock-raising profitable. As a consequence, the drought produced much the same effect as the earlier ones of 1871–

1873 and 1893–1895. The series of dry years exhausted the hope and the credit of the newcomers, and their ranches were sold to the stockmen or simply abandoned. This process can only be repeated as a consequence of future droughts, until the West recognizes that much of its area can never be used profitably for any purpose except that of stock-raising. This realization can hardly come until repeated failures at dry-farming have demonstrated that extensive regions can never be used for crop production. These areas can be determined with much accuracy at present, both by means of the indicator vegetation and by means of crop failure and the abandonment of farms. This is especially true when the rainfall record is taken into account. All of this is of little avail, however, until the State recognizes that settlement is one of its important functions, and that it can not be left to political immigration bureaus or to unscrupulous real-estate dealers. When it does recognize this, the settlement of the State's lands will be put into the hands of the experiment stations, or of scientific commissions, such as that of California. Only when this is done will the settler be able to make an adequate home and the State to profit by his production.

Rubber Plants, by H. M. Hall and Frances Long.

During the past three years, about 340 sets of specimens, representing 250 species, have been assembled from all parts of the West and subjected to chemical examination for rubber. The results show that rubber occurs in a much larger number of species than heretofore supposed and that the amount present in some of them is sufficiently great to justify experiments looking toward their cultivation on a commercial scale. At any rate, the results thus far obtained, and especially the chemical examination of this large number of native plants, will be of definite scientific value. Furthermore, they serve to indicate the species and forms which are most likely to yield results of commercial importance if followed up on a large scale. Several kinds of milkweeds of the genus *Asclepias* are the most promising for further study. While earlier examinations by rubber chemists indicated about 2 per cent as the maximum rubber content of these plants, it is now established that as high as 8 per cent of rubber may be obtained from the leaves by the selection of proper species and ecologic forms. In one leafless desert-species the rubber content is about 5 per cent of the entire plant.

It is reasonably certain that the rubber content of milkweeds can be considerably increased through breeding and selection. Since some of them grow readily on poor soils unsuited to agricultural crops, it is not beyond the range of possibility that they may in time constitute an important crop of the arid West. For this reason, some attention has been given to the conditions of growth and the formation of rubber

in these plants. Experiments have been carried on to determine the fluctuation in the percentage of rubber at different seasons and under varying ecologic conditions. Comparisons have been made between the original stands and second-growth shoots, as well as the study of the behavior of plants after cropping. Seeding experiments have not yet been conducted on a large scale, but both germination and garden tests indicate that there will be no difficulty in growing the plants from seed.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. *Study of Fundamental Problems of Geology.* (For previous reports see Year Books Nos. 2–18.)

The principal work of the year has been a comparative study of the earth, Venus, Mars, and the moon, with special reference to the relative amounts of shrinkage they underwent during their formative stages and the light this might throw on the deformations recorded in the earth's great features.[1] Incidentally the inquiry led to a special consideration of the formative processes themselves. This appeared essential because estimates of deformation under the molten and the accretional hypotheses, respectively, are rather radically different not only in amount and kind, but also in the time of occurrence. Under the molten hypothesis, no deformation, in the ordinary geological sense of the term, has been assigned or seems assignable until the fluid state was at least partially replaced by a solid crust, and this crust only began to form after the assembling process was essentially complete. During the assembling the fluid state offered ideal opportunities for chemical combination and physical adjustment, so that, except in so far as heat prevented, the potential resources of shrinkage should have been essentially exhausted before their shrinkage effects could be recorded by deformation in a solid form. Little more than the shrinkage effects of cooling after solidification could be registered in diastrophic features. On the other hand, if the earth were built up largely by accretions in a solid state, especially if these were minute and laid down in random fashion, a much larger proportion of the potential resources of shrinkage would be registered in fixed solid forms. Moreover, this would take place while the formative processes were in progress, and would thus be subject to their influence. The deformations under the two hypotheses, therefore, differ widely in amount and in kind, as also in the stages at which they were chiefly effected.

A previous examination of the great features of the earth had seemed to reveal an amount of deformation much greater than has usually been assigned under the molten theory and somewhat greater also than had

[1] With the permission of the President of the Institution, some of the preliminary results of these studies have been published in the Journal of Geology, constituting articles x, xi, xii, and xiii (1920) of a series of papers entitled "Diastrophism and the Formative Processes."

been inferred from an accretional formation. This prompted a search for evidences bearing on the total shrinkage of the earth, and the comparison of the earth with its neighbors suggested itself.

THE SHRINKAGE OF THE EARTH DEDUCED FROM A COMPARISON WITH ITS NEIGHBORS.

The study began by a comparison of the respective volumes, densities, and masses of the earth with the same properties of the next outer planet, Mars, of the next inner planet, Venus, and of its own satellite. These four bodies form a little astronomic group occupying less than 3 per cent of the outward reach of the sun's sphere of control. Their dynamic environments, while in process of formation, were therefore so similar that they can be compared with advantage. The method consisted first in building up theoretical earths by adding to each of the three other bodies matter of its own kind and density until the whole equaled the mass of the earth, and computing the respective volumes thus attained. Then, having shrunk each body to the volume of the earth, the amount of shrinkage involved was determined. The results are shown in table 1.

TABLE 1.*

Basis of parity-earth.	Density water =1.	Present radius.	Present volume.	Parity volume.	Parity radius.	Shortening of parity radius.	Shortening of parity circum.	
			cu. miles.	*cu. miles.*	*miles.*	*miles.*	*miles.*	°
Moon..	3.34	1,080	5,276,678,626	430,353,000,000	4,684	725	4,555	66
Mars...	3.58	2,170	42,802,469,494	401,502,000,000	4,577	618	3,883	56
Venus..	4.85(?)	3,851	239,226,992,649	296,367,000,000	4,136	177	1,112	16
Earth..	5.53	3,959	259,923,849,377	....	3,959	....	....	....

*The parity-earths may be derived either from the relative densities or the relative masses. The results, however, are not strictly identical in all cases, doubtless because the figures adopted are the weighted means of different methods of determining the masses and densities and these thus lose strict consistency with one another. The differences are not enough to affect seriously the order of magnitude of the shrinkage results.

These results exceed any shrinkage heretofore postulated, so far as known. They are abundantly ample to meet the unexpectedly large shrinkage requirements that had given rise to the inquiry.

The rest of the study was an effort to see whether these results were subject to serious question or required any radical qualifications. The reasonableness of trying to account for these results by arbitrary assignments of intrinsically lighter and heavier material was considered, but the conditions of the case were found not only to lend no justification to this, but to clearly imply that the more massive and denser bodies contained the *smaller proportions* of inherently heavy material. As all four bodies are essentially solid, and there was found to be not only an increase but a growing rate of increase of mean

density from the smallest to the largest, they were studied as though they represented the stages of growth of a single body. For this purpose 1 per cent of the earth-mass was taken as the unit of increase, and an ideal parity-earth built of meteorites taken as having a mean density of 3.69 (Farrington's determination) as a standard of comparison. It is to be noted that much porosity probably prevailed in the outer zone of the bodies of little or no atmosphere, while the hydrospheres of Venus and the earth caused the filling of pores by inwash and cementation. Table 2 gives the results of the comparison in this form.

TABLE 2.—*Comparison of actual bodies with corresponding ideal parity bodies built of meteorites.*

Body.	Radius actual body.	Radius parity body.	Radii differences.	Mass units (unit=1 p. ct. earth).	Relations, actual to parity body.
	miles.	*miles.*	*miles.*	*p. ct.*	*miles.*
Moon......	1,080	1,045	− 35	1.22	−28.7
Mars......	2,170	2,148	− 22	10.65	− 2.0
Venus......	3,851	4,218	+367	80.70(?)	+ 4.5
Earth......	3,959	4,531	+572	100.00	+ 5.7

It appears from this table that, on the assumption that the whole work was compressive and making no allowance for the lighter matter of the large bodies, the moon, built up as it actually was, failed to compress itself to the assumed meteorite standard by 28.7 miles per unit of mass-growth, Mars by 2.0 miles per unit, while Venus compressed itself beyond the meteorite standard to the extent of 4.5 miles per unit, and the earth by 5.7 miles per unit. The trustworthiness of the meteorite standard does not affect the real relations of the four bodies; the standard is only a convenience in making the comparison. Subsequent studies favor a lower rather than a higher mean density for meteorites. If these four bodies fairly represent four normal states of growth in a single body, their significance is highly important, for they imply that the diastrophism which gave rise to the high density and profound deformation of the earth took place, either actually or potentially, during its formation and chiefly in the latest stages. Because of this radical importance, it was felt to be imperative to examine with care all related factors or assumptions as fully as practicable to see if in any essential way they affected the significance of these conclusions. In making this examination, special attention was given to the dynamic conditions that controlled planetary evolution in the region of the earth under the hypotheses postulated, particularly the relations of the formative processes to the spheres of control that limited and governed them.

THE BEARINGS OF NUCLEAR CONCENTRATION ON THE PROBLEM OF SHRINKAGE.

Though the evolution of the planets, along the familiar gaseous lines commonly accepted during the last century, seemed excluded, it appeared advisable to reconsider such an evolution under the specific conditions that affected the bodies under comparison. In this reconsideration of a possible derivation from a rotating gaseous nebula by centrifugal action, the part played by disruptive action within the Roche limit was made the key to the inquiry. Studied from this criticial point of view, it seemed clear that the separation of matter from the equator of the nebula would necessarily take place, not only molecule by molecule, but that these molecules would ultimately be thrown into orbits, so that aggregation from these would follow the methods of planetesimals. Within the Roche limit aggregation beyond minute sizes would be inhibited, and outside that limit for some distance the conditions would be distinctly adverse to any massive assemblage. Aggregation of the planetary order, if it could take place at all under these conditions, would require an extremely long period with corresponding physical states; precipitate condensation would be quite out of the question. Generalized, it appears that the only tenable way in which planets of the terrestrial order could have descended along gaseous lines was through gases definitely bunched in some form and sufficiently dense to permit self-control; otherwise the gases must have been dissipated into planetesimals or their dynamic equivalents.

The aggregation of planetary nuclei under the planetesimal hypothesis is of the gaseous type, in their early stages at least. This seems to be the only line postulated by a tenable hypothesis that offers any probability of a continuous gaseous descent of the minor planetary bodies, attended by such physical states as are derivatives from the gaseous condition. The concentration of a planetary nucleus of this type, however, is by no means the simple process which gaseous condensation has commonly been thought to be. There are several accompanying agencies which rather radically modify the process. Four of these were studied in some detail.

I. The Influence of Inherited Motions.

The planetary nuclei postulated by the planetesimal hypothesis consisted of such of the central parts of the solar outbursts as had sufficient self-attraction to remain under self-control after they had been projected into planetary space. At the distance of the earth, matter in spherical form having a mean density of 0.0011+, atmospheric standard, would control itself against the differential attraction of the sun, if affected merely by motions common to the whole mass, but it would be easily dissipated by differential motions of any moment within its own mass, the dispersed matter in the main becoming plan-

etesimals. If the mass of the nucleus were large and much concentrated toward the center, its future career would be secure; but if small, unless very highly concentrated, its persistence would be critically dependent on special conditions. Scrutiny of the conditions that affected the smaller planetary types was therefore imperative. The motions imparted by the eruptive and projective action of the sun were the first source of hazard.[1] Turbulent, vortical, and rotatory motions would be almost inevitably inherited from the solar expulsion. Turbulent motions prevail in the sun and additional turbulences must have been generated by unbalanced thrusts and drags incident to eruption. More or less of vortical or eversive motion almost inevitably arises from eruptive action. The mass was already rotating as a part of the sun, and doubtless received additional impulse toward rotation in the eruptive act. All these motions more or less critically conditioned the early evolution of the smaller nuclei. Convective action, as it developed in each nucleus after its expulsion, was necessarily built upon these inherited motions and took form in adaptation to them. The convection currents were not, therefore, simple vertical cycles, as naturally enough pictured in static quiescent bodies. They must have been highly complex, more or less gyratory, and even tortuous. In so far as they were specially eversive, they were much more effective in discharging internal heat in the smaller order of bodies than simple thermal convection.

II. The Sifting of the Solar Gases.

When the material for the planetary nuclei was ejected from the sun, it consisted essentially of highly mixed hot gases, doubtless essentially alike in all nuclei, except perhaps for some systematic gradations. The giant planets seem to have remained essentially gaseous, as implied by their densities: Jupiter 1.25, Saturn 0.63, Uranus 1.44, and Neptune 1.09. The material for the terrestrial group, however, was so changed as to form essentially stony or metallic solids with notably high densities: earth 5.53, Venus 4.85(?), Mars 3.58, and Mercury 4.48(?). Their atmospheres formed only a negligible proportion of their masses. The planetoids and smaller satellites seem to be quite without appreciable atmospheres and are doubtless formed wholly of stony or metallic material. It is clear, therefore, that in the formative process there was much sifting out of the lighter molecules that were mixed with this stony and metallic material as it came forth from the sun. Such sifting is precisely what the kinetic theory of gases requires under such conditions. The escape of the light molecules from the smaller nuclei should take place with great facility as long as they were still in the hot, expanded condition that

[1]Respecting the mode of propulsion, the discoveries of Pettit relative to the eruptive prominences of May 29 and July 15, 1919, are very instructive. Edison Pettit, The Great Eruptive Prominences of May 29 and July 14, 1919, Astrophys. Jour., vol. 50, 206–219, Oct. 1919.

followed their emergence from pressure within the sun. The great nuclei, on the other hand, might have been able to hold even the lightest gases at all stages, except that a few particular molecules might acquire very exceptional cumulative velocities and escape. Between the very small and the very large bodies there thus arose a radical distinction, but they graded into one another in the middle of the planetary series. Numerical inspection showed that nuclei of the smallest order of bodies, including all of the planetoids and the smaller satellites, and possibly the nuclei of the terrestrial planets, would probably not be able to hold under control even the molecules of the stony and metallic substances at the temperatures at which they would be volatile in appreciable quantities. The concentration of these bodies must therefore probably have followed some other than the strictly gaseous line of condensation—some line in which the constituents were more massive and less active. The probable nature of this line revealed itself through the considerations under the next head.

III. The Formation of Precipitates, Precipitate Aggregates, and Brownian Mixtures.

Following the emergence of the gaseous masses from the solar pressure, there must have been notable cooling by expansion as well as by radiation. Hence the precipitation of such substances as were liable to it at the temperatures reached seems inevitable. This is the more certain because it is highly probable that precipitation had already begun in the sun; at least the photosphere is commonly explained as a zone of such precipitates. These precipitates would be scattered through the gas and would have the effect of Brownian particles and the subsequent evolution is to be treated as that of a Brownian mixture. While such a mixture is closely analogous to a true gas, it has points of difference growing out of the replacement of molecules by aggregates which are indefinitely more massive and are affected by inelasticity. In nuclei of sufficient mass, the Brownian gaseous mixture would doubtless give rise to a central magma that would in turn evolve as a liquid Brownian mixture, owing to the progressive formation within itself of crystalline or concretional aggregates. These aggregates, it is believed, would gather into solid planetary cores.

In the smaller and more open nuclei, however, such molecules as remained free, while the stony and metallic substances were forming precipitate aggregates, would escape with facility until the supply was exhausted, and so only the precipitate aggregates would remain as the residue of a quasi-evaporative process. The Brownian mixture would thus give place to a cloud of precipitate aggregates. Though minute, these aggregates might yet be very high multiples of the heaviest molecules, and being in addition somewhat inelastic, they would be much less active and much more amenable to mutual con-

trol. The subsequent assemblage would not then be that of a gas, but would apparently proceed by a process quasi-gaseous in part and quasi-orbital in part. A reduction of the collision-rebound type of action would apparently follow with a relative increase of orbital motion. Computation based on the data given in table 3 seemed to show that all the atmosphereless bodies of the solar system, and probably those that have small atmospheres, were formed along this line of descent which may be looked upon as an alien derivative from the true gaseous line of descent.

TABLE 3.—*Dynamical properties of ten representative bodies of the terrestrial and smaller classes.**

The ten bodies.		Statistical properties.			Dynamical properties.			
a	*b*	*c*	*d*	*e*	*f*	*g*	*h*	*i*
No.	Name.	Diam. in miles.	Density water = 1.	Mass earth = 1.	Surface gravity g = 1.	Parabolic velocity in miles per sec.	Velocity of retention in miles per sec.	Diameter of sphere of control.
I........	Earth...	7,918	5.53	1.0000	1.00	6.95	4.91	1,240,000
II........	Venus...	7,701	?4.85	0.8077	0.85	6.33	4.48	1,156,000
								(836,000)
III.......	Mars...	4,339	3.58	0.1065	0.36	3.06	2.16	588,000
								(898,000)
IV.......	Ideal....	3,407	3.50	0.050	0.27	2.38	1.68	458,000
V........	Moon...	2,160	3.34	0.0122	0.16	1.47	1.04	286,000
								(50,000)
VI.......	Ideal....	1,000	3.30	0.001202	0.075	0.68	0.48	132,000
VII......	Ideal...	500	(a) 3.30	0.0001503	0.0375	0.34	0.24	66,000
			(*b*) 5.00	0.000228	0.057	0.42	0.30	76,000
VIII.....	Ideal....	100	(*a*) 3.30	0.000001202	0.0075	0.068	0.048	13,200
			(*b*) 6.00	0.000002186	0.0137	0.123	0.087	16,000
IX.......	Ideal....	50	(*a*) 3.30	0.0000001503	0.00375	0.034	0.024	6,600
			(*b*) 6.50	0.0000002960	0.0074	0.067	0.047	8,320
X........	Ideal....	10	(*a*) 3.30	1.202×10	0.00075	0.0068	0.0048	1,320
			(*b*) 7.00	2.550×10	0.00160	0.0144	0.0102	1,700

*Computations by W. D. MacMillan.

It is not altogether clear which of these two lines of descent was followed by the nucleus of the earth, for the size of this nucleus relative to the adult mass of the earth depends upon considerations which it seems best not to try to evaluate until the inquiry is more advanced. If the concentration of the earth nucleus followed the derivative line just sketched, the core of the earth was probably solid at all stages and the whole of the bodily evolution essentially accretionary, but if it followed the gaseous-Brownian-mixture line, the method of solidification of a liquid core under such peculiar conditions needs reconsideration on the lines that actually obtained, as nearly as these can be determined by patient and critical analysis, and not on the suppositious lines of ideal isolated gaseous bodies.

In such reconsideration, precipitation from a mutual solution should replace surface refrigeration from a supposed melt, since it is well established that magmas are to be regarded as mutual solutions rather than melts. The main line of the core-forming process must have lain in the formation of crystals or concretions by supersaturation in connection with chemical reactions. While the genetic phases of petrological science have not yet reached a stage that permits an altogether confident opinion as to just how precipitation would proceed in the deep portions of such a mutual solution, it may be safely assumed that the gyratory circulation due to the rotation of the body would affect both the precipitation and the lodgment of the precipitates. The solid nucleus formed under the shaping influence of such a gyratory circulation would certainly not be strictly spherical and could hardly be symmetrically spheroidal; it would depart from these in ways that adapted it to the conditions of precipitation and lodgment along the current courses.

The importance of this consideration lies in the obvious fact that any solid core formed at the center of the earth would be the foundation on which the whole overlying portion of the solid globe would be built, and hence it must influence all the subsequent diastrophism. As already noted, the comparison of the earth with its neighbors brought out the very significant conclusion that the high densities of the larger bodies were due mainly to the mass-effect of the later additions. These later additions do not in themselves appear to be specially dense, but rather the opposite. Hence it is logical to conclude that the increased density of the more massive bodies was chiefly due to progressive compression, selective removal, readjustment, and reorganization of material in the deeper horizons as the bodies grew. Since, then, the core was the part most to suffer this compression and readjustment of material, its specific shape and structure as first formed are matters of no little importance. While the present status of petrology requires reserve in forming a precise picture of the formation of the solid core from the magma, it is clear that the method of precipitation and lodgment of the precipitates must be worked out on the basis of a mutual solution stirred by a gyratory circulation rather than the old notion of the superficial freezing of a quiescent melt.

IV. The Differential Stresses under which the Formative Processes Took Place.

The group of stresses that arose from changes in the rate of rotation, from tides, from nutational forces, and other sources, brought to bear upon the forming earth-core conditions that could scarcely fail to influence rather radically its development. Those that take the form of zonal harmonics of the second order may be regarded as representing all general stresses from without. These give rise to strains that assume the form of bulged equators and flattened poles, as in rotational deformations, or the form of polar cones embracing a depressed equator

between, as in tidal deformations. In all these cases of deformation, the stresses permeate the whole body and are greatest in the central parts. Sir George Darwin[1] found that for a homogeneous, incompressible earth the stress ratios would be 8 at the center, 3 at the equator, and 1 at the poles. For a compressible earth they would be relatively lower at the surface and higher at the center. For a certain compressibility the surficial stress-differences disappear and those at the center increase one-sixth in value. The actual stress-differences generated by changes of rotation, tidal attractions, and other influences of this type may be taken as ranging from vanishing quantities at the surface to 9 or 10 at the center. These stress-differences are superposed on hydrostatic stresses of much higher orders. While the tidal stresses are small, they are not only frequent and rhythmical, but follow persistently in a given direction. In certain respects their effects are thus cumulative. Tidal influences of some sort must have arisen as soon as the segregation of the planetary nuclei began. Changes in rotation were probably frequent in the formative stages and probably then had high deformative value. The combination of these agencies is regarded as highly potential, because they brought to bear higher stresses on the central parts than on the outer parts, thus giving rise to a graded squeeze with least resistance outwards. Obviously this graded squeeze would tend to force surfaceward the less-resisting matter. The stresses worked in rhythmic kneading fashion. They doubtless had special effectiveness in the formative stages when the masses were youngest, and when self-compression, selective removal, readjustment, and reorganization were most easily accomplished. The combination was admirably fitted to give that increasing distribution of density and rigidity centerward, towards which the united testimony of astronomical evidence, body tides, polar nutation, and seismic data are now so strongly converging. The normal results of this combination of forces are equally in harmony with the results reached in the present inquiry by a comparison of the earth, Venus, Mars, and the moon.

THE BEARINGS OF THE SIZE AND RATE OF INFALL OF THE PLANETESIMALS ON THE LIQUIDITY OR SOLIDITY OF THE EARTH.

Under the planetesimal view the concentration of each nucleus was followed by growth from the infall of planetesimals. The chief sources of planetesimals were (1) dispersion by solar propulsion and (2) molecular escape. The latter was important only where self-control was limited, but, as already pointed out, all the solid bodies must have lost much of their original substance, and this was probably due in the main to molecular activity. The matter so lost would be subject to recapture, though it could not usually be held permanently unless cool-

[1] Scientific Papers, vol. 2, 475–481, 1908.

ing or growth had changed the holding power of the parent body. Planetesimals from both sources were liable to cross the paths of nuclei at any revolution and so be subject to capture. Such capture doubtless began to take place as soon as they returned from their first excursions; later it was liable to take place only on such periodic returns.

The size and rate of infall of planetesimals are important in this discussion because they have bearings on the liquidity or solidity of the earth, and because it has been urged that impacts of large planetesimals or planetoids may have caused the pitted nature of the moon's surface. The size and rate of infall of planetesimals have therefore been carefully reconsidered, giving special attention to the light thrown on the subject by their dynamic conditions. The subject is much clarified if it is noted that at the outset essentially all planetesimals were either separate molecules or minute precipitate-aggregates projected directly from the solar outbursts into orbits of the planetary type, or else were separate molecules that escaped from nuclei of limited gravity. Their sizes at later stages were determined by such growths as could arise from chance accession or from the union of these minute initial bodies with one another while in their orbital flights. There was no condensation of the gaseous type, for each planetesimal was under the control of a moving force so high as to render their mutual attractions relatively insignificant. Only under rare conditions—chiefly when a delicate balance of the higher order of forces occurred—could mutual attraction have any appreciable effect. Electric attractions and repulsions probably helped aggregation rather notably up to certain sizes, but it was probably ineffectual beyond. Collisions and triturations worked against growth probably more than for it, and exfoliation due to changes of temperature tended to reduce their masses after they became large enough to suffer from differential heating. The satellitesimals of Saturn's rings, the largest of which Bell places at 3 meters or thereabouts, are probably the best naturalistic guide to a definite judgment now available.[1]

It is an error to suppose that the planetesimal theory postulates a gradation from planetesimals to planetoids. The latter are formed in a distinctly different way, by the concentration of nuclei. Planetoids probably represent the smallest class of bodies that could be formed in this concentrative way in the inner portion of the sun's sphere of control where its gravitative stresses are adverse. The inquiry shows that none of the atmosphereless bodies could be formed directly by gaseous condensation; they were probably formed by the indirect precipitate-aggregate method. This view is supported by the fact that no planetoids are observed as near the sun as the earth. They appear first at about the distance of Mars, where the dynamic environ-

[1]Louis Bell, Physical interpretation of Albedo II: Saturn's Rings. Astrophys. Jour., vol. 50, 1-22, July 1919.

ment is less restrictive. It is concluded, therefore, that there is a notable gap between the smallest planetoids formed by this phase of collective concentration and the largest planetesimals built up from molecules or precipitate-aggregates by orbital accessions.

The state of aggregation of the planetesimals has really little bearing on the fluidity or solidity of the earth, for the more they were united before they fell to the earth the fewer there were to fall. In uniting they exhausted some of their potential energy, which otherwise they might have carried into the earth, while in compensation the united masses were more effectual in overcoming the resistance of the atmosphere.

The rate of infall of planetesimals was studied from the probable frequency with which in the pursuit of their orbits they would cross the orbit of the growing planet, combined with the chance that the planet would be there at that instant. The case can be illustrated in its most favorable aspect by considering the courses of the molecules that escaped from the earth nucleus into planetesimal paths by reason of high molecular velocities during its hot early stage. It is easily shown that such escaping molecules would, with extremely rare exceptions, take planetesimal orbits, whatever the direction in which they were shot forth from the earth nucleus. After being shot forth into such orbits they would come back to the virtual point of escape in about a year's time, but the chance of reaching the node at the instant the planet was passing would be adverse unless they had acquired an orbit of the same periodic value, which would not be the common case, for most molecules escaping in this way would take either larger or smaller orbits or else more elliptical or less elliptical orbits, or both. Their future chances would depend on modifications of their orbits due to perturbations and precessions, whose effects would be slow and uncertain.

Somewhat less definite conditions controlled the relations of the orbits in the case of planetesimals formed directly by the original solar outburst. On the whole these were less favorable to capture by the earth nucleus. The conclusion, therefore, seems imperative that infalls at least could not be precipitate. There seems little ground for assigning a sufficient frequency to cause a general molten condition of the earth, even if it were not protected by its atmosphere.

The atmosphere probably reached a protective depth and density by the time the earth was one-tenth grown, if indeed the nucleus itself was not more massive than this at the start. At present, very small infalling bodies—many of which have velocities much higher than can be assigned planetesimals—are generally consumed or arrested above 30 miles from the earth's surface. Very little thermal effect on the solid substance of the earth can therefore be assigned infalling bodies of such sizes, even if their number were vastly increased. Even the larger meteorites bring little heat to the surface of the earth, for their moving

energy is mainly converted into heat by atmospheric friction earlier in their courses when their speed is greatest, and this heat is largely consumed in melting a surface film which is mainly dissipated along their paths. The heating of the atmosphere would therefore be the first effect of infalling bodies, and only when it was raised to sufficient temperature would melting of the solid earth follow, an event that seems extremely improbable.

In support of the foregoing conclusions, which rest in some large measure on theoretical considerations, there are several sources of concrete testimony whose convergent import has no little value.

THE TESTIMONY OF THE ZODIACAL PLANETESIMALS.

The position, relations, and lens-like form of the Zodiacal Light imply that the particles which reflect it are maintained by orbital dynamics of the planetary type. If so, these particles are to be regarded as planetesimals. They are interpreted either as remnants of the original planetesimal system or as more recent products due to the projection of solar matter so close to the planets that it is drawn forward into elliptical orbits by them. If either interpretation is correct, they give explicit testimony as to the sizes of planetesimals, for they are clearly minute. No individual particle has ever been detected, although the lens which they collectively form envelopes the earth and makes it certain that some of them are near us at times.

THE TESTIMONY OF THE CRATERS OF THE MOON.

The crater-like pits of the moon have sometimes been attributed to the impacts of large planetesimals or planetoids. The results of the inquiry already cited in respect to the size of the planetesimals, as well as the absence of planetoids in the terrestrial region, are quite adverse to the theory. In addition, the verticality of the pits seems to be an insuperable objection, for bodies pursuing orbits would strike the moon's surface obliquely in many if not most cases. The alternative theory that the pits arose from explosive action of the volcanic type is supported by their vertical axes, their circular outlines, the symmetrical distribution of débris, and other features. Now, the volcanic interpretation has usually been thought to imply a molten state of the moon, at least formerly. Precisely the opposite inference is here held to be much more logical. These volcanic craters are held to be good evidence that the moon has never been in a holo-molten state, though of course it held local hot spots such as give rise to terrestrial volcanoes. The moon now holds no appreciable atmosphere. It is presumably more massive and colder than in its earlier stages. There seems, therefore, to be no ground for assigning it the power of holding free volcanic gases at any stage of its history, least of all when in a molten state. All gases that could be set free by a liquefying temperature should certainly have been boiled out and have escaped because

of their high molecular activity and the limited gravity of the moon. Hence no such supply of gases as is necessary to actuate the great explosions should have remained. On the other hand, if the planetesimals that entered into the makeup of the moon carried in a certain amount of occluded or combined gases, as they naturally would, and if also the porous mass of the growing body were penetrated by molecular planetesimals of the volatile type, as would be almost inevitable under the assigned conditions, and if they were held there by capillary force or surface adhesion until they became entrapped by the continued growth, there would be incorporated in the growing body the potential supply of gas required for explosive action. There need then only follow central compression, the forcing of the gaseous matter toward the surface, and radioactive generation of heat to develop an effective explosive mechanism. The porous structure of the outer part would furnish almost ideal mechanical conditions for effective pit-formation, for the heaping up of symmetrical rims of clastics, for the projection of radial lines of débris, and for the related phenomena that characterize the moon's topography. The surface features of the moon are therefore held to be cogent evidence that the moon escaped a holo-molten state. On the contrary, localized eruptive action might be developed to a remarkable degree from the conditions normally assignable to an accretional formation.

THE TESTIMONY OF TERRESTRIAL VULCANISM.

The same line of argument applies to the earth, with the unimportant qualification that our planet holds an atmosphere whose constituents exert a small partial pressure on its surface. To the extent that an atmosphere could be held if the planet were in a molten state, the magma could hold gases in equilibrium with the partial pressures of the enveloping gases. This amount would certainly be limited, and it is to be noted that the partial pressure would be felt by the lavas at all stages of extrusion and would not constitute an explosive agency. To meet the requirements of the case, a competent supply of explosive gases must be concentrated at the point of explosion. A protracted molten state, during which all free and freeable gases should have been boiled out and the excess dissipated, would seem to be a poor preparation for explosive vulcanism. When the critical features of volcanoes are closely considered, they strongly support the view that eruptions are distinctly local and independent. They have no obvious connection with any liquid sheet or reservoir left over from a general molten state.

THE TESTIMONY OF THE ABERRANT BODIES OF THE SOLAR SYSTEM.

Interpreted on the planetesimal basis, the normal phenomena of the solar system thus yield various distinctly concordant phases of testimony bearing on the critical points here at issue. To supplement this, it was thought worth while to inquire whether the aberrant phe-

nomena of the system would also shed similar light, or would their testimony be as diverse as they are aberrant? The recognized bodies of this class include meteors, meteorites, and comets. While some of these may be alien to the solar system, the common types were viewed as merely aberrant manifestations of the same dynamic agencies as those that gave rise to the normal members, the planets, planetoids, planetesimals, satellites, and satellitesimals. To justify any treatment at all on this basis, definite working concepts of the relations of the aberrant to the normal members are required involving both origin and active interrelationships. For this purpose, three mutually consistent hypotheses were developed. In these, meteors, meteorites, and comets were regarded as features of the same dynamic source and import. The special cometic phenomena were thought to be due mainly to the alternate passage of small, loosely organized bodies through extremes of heat and cold, such as are found at the two ends of their highly elliptical orbits. The main function assigned to these extremes were deep cooling, shrinking, and riving, attended by the absorption of gas material in the form of free molecules in the long outer swing, while during the inner swing about the sun there was exfoliation and trituration under its influence, accompanied by the discharge and repulsion of the absorbed gas material, together with trituration dust. The distinctive features of the comets, however, have little bearing on the main subject of this inquiry and are left with this inadequate statement. Their dynamical features carry the main significance, and these they share with the meteorites. In both cases the orbital planes lie in all azimuths, the revolutions are retrograde as well as forward, and the orbits are highly eccentric. The meteorites have distinct peculiarities of organization, structure, and fragmentation which, to justify the hypotheses offered, must spring naturally out of the assigned conditions. The effort was to find phases of the genetic and dynamic processes already assigned the normal features of the solar system that would fit the aberrant members equally as well. There was the more reason for this because of the growing conviction of students of these seemingly erratic bodies that they are really members of the solar system.

1. The first hypothesis assumes that, previous to the genesis of the present planetary system, the sun had secondaries of such an order as could be developed by it without the cooperation of any other body, *i. e.*, distinctly small secondaries evolved on the same principles as those that give rise to orbital ultra-atmospheres; and that these small bodies were thrown into irregular, highly elliptical orbits by the passing body that cooperated in developing the present planetary system. Such of these small bodies as were given very long elliptical orbits experienced those extreme contrasts of conditions between their outer and their inner courses to which cometic characteristics are assigned

in the ways above suggested. The disintegration of these gave rise to meteorites.

2. The second hypothesis assumes that solar gases and precipitates were projected by forces of the kinds disclosed by the observations of Pettit on the solar prominences of May 29 and July 15, 1919,[1] into the outer regions of the sun's sphere of control, where solar attraction was feeble and the attractions of outer bodies relatively strong. During this outer flight the pull of some star, group of stars, or outside center of attraction drew the ejected matter aside from its path sufficiently to cause it to swing by the sun on its return and take a highly elliptical orbit. The plane of this orbit and the direction of revolution would be determined by the deviating attraction, so that a system formed by a large number of such deviations would be very heterogeneous in orbital features, save that high ellipticity would be a common characteristic. The principles of aggregation and lack of aggregation herein previously sketched would apply to the projected matter in this case. In so far as the projected matter retained self-control, it would assemble by the precipitate-aggregate method into clouds or still more concentrated bodies which by hypothesis would function as comet-heads. These would be subject to all the vicissitudes of temperature and of alternate absorption and evolution of gaseous material sketched above and so function for a time as comets and ultimately be disintegrated into meteorites. In so far as the projected solar matter was too highly dispersed for mutual control, it is assumed to have passed directly into meteoritic matter of the minutest type. Such minute meteoritic matter abounds in interplanetary space in such prodigious numbers that many millions are picked up daily by the earth. The formation of precipitate-aggregates in the methods previously sketched seems to furnish an apt explanation of the origin of chondrules and other minute integers that so largely make up meteorites. The collisions of these little bodies as they were entering into the formation of larger bodies seems to account for the intimate brecciation, the little specks of glass of singularly circumscribed extent—regarded as evidence of suddenly cooled liquid spots—the strange mixtures of stony and metallic matter, and other distinctive features.

3. The third hypothesis is conditioned by the pre-existence of the present planetary system. It supposes that in any given case the ejected solar matter passed so near some one of the more massive planets that it was thrown into an elliptical orbit in a way similar to the preceding and with similar results. A certain portion of the matter so diverted would take orbits of the planetary type so far as their planes are concerned, but only a part of these would have a planetoidal degree of circularity. Other portions would have orbits whose eccentricities, whose planes, and whose directions of revolution were as vari-

[1]Astrophys. Jour., 206–219, Oct. 1919.

ous as are those of meteorites and comets. Certain comets are known to have orbits definitely related to the giant planets. This relation is commonly regarded as the result of reduction from larger and more eccentric orbits by the planet's influence. Without questioning the validity of this, it may be held that in some cases the comet arose *de novo* from the planetary action as here suggested.

These three hypotheses are consistent with one another and may all be true. They have the merit of being made to rest on the same genetic basis as the planetary system itself. The scheme thus gives unity to the whole solar system.

If this be the true line of interpretation, *the masses of meteorites and their methods of infall throw a flood of light on the sizes and modes of infall of the planetesimals, for, by this interpretation, they are bodies of like origin and like general conditions.* Now, on a conservative estimate, there are 100,000,000 minute meteorites ("shooting stars"), that are so small as to be wholly dissipated in the upper air, for every one that is massive enough to reach the earth as a visible body. Even of the latter none is known to exceed a dozen feet in mean diameter; none of them has been seen to produce melted soil or rock where they strike. The supposed meteorite responsible for the crater of Coon Butte requires special consideration which cannot be given here. Even if given the full benefit of all doubts, this meteorite does not call for any modification of the general statement that meteorites are competent to produce only very local and limited liquefaction. So far as their evidence bears on the size, rate of infall, and liquefying power of their relatives, the planetesimals, it is wholly in accord with the deductions hereinbefore drawn from theoretical considerations.

CONCLUSIONS.

1. The density of the earth compared with that of Mars, Venus, and the moon—all formed under similar genetic conditions—implies a shrinkage more than sufficient to justify the exceptionally large estimate of deformation which prompted the inquiry.

2. Since this large deformation is recorded in solid matter, the requisite shrinkage must have taken place after the solidification of the earth was sufficiently advanced to register it. This favors the view that solidification of the requisite type began early.

3. The amount of this shrinkage is so large as to imply that the potential resources of shrinkage were conserved in a high degree until the solidification requisite for a deformative record had been realized. As the accretion of solid clastic material retains the possibilities of shrinkage in a higher degree than formation in a molten state, the former is favored.

4. The inquiry gives no warrant for supposing that any larger proportion of inherently heavy matter entered into the composition of the two larger bodies, the earth and Venus, which have the higher densities, than into the two smaller bodies, Mars and the moon, which have the lower densities, but quite the opposite; nor does it justify any other arbitrary supposition to account for the observed densities. The density ratios seem to be a normal effect of the genetic conditions, for they correspond to the ratios of the differential stresses under which the earth and presumably its neighbors were formed.

5. The marked increase of density per unit of increase of mass implies that the higher densities of the larger bodies are mass-effects assignable most consistently to compression abetted by the squeezing out of light material and of substances not suited to take on the denser forms required and by readjustments and reorganizations of the material retained in the interest of high density.

6. As the mean density of the earth is about twice that of its surficial layer, and as a gradation downwards is implied by several lines of evidence, the inference follows that the compression and the allied readjustments were chiefly effective in the central parts of the earth—in other words, the central parts were the chief locus of diastrophism, using this term in a comprehensive sense to include all changes of form or density that were recorded in a solid state. The diastrophism in the deeper parts may not improbably have largely taken on the more intimate forms affected by individual molecular changes as observed in metamorphic rocks rather than declared deformations of the crumpling and contortional order, but these are not necessarily excluded.

7. Since the implied cause of this chief diastrophism, added mass, came into effect as the growth of the planet proceeded, it follows—when due allowance is made for the possible lag of effect behind cause—*that the greatest diastrophism took place while earth-growth was in progress*, a conclusion radically at variance with the inherited view that deformations began only after the earth mass was assembled as a liquid globe and had cooled so far that congelation of its surface afforded the means of a deformative record.

8. The reexamination of the formative processes assigned by etn planetesimal hypothesis disclosed the inapplicability of deductsiqo from *unmodified* gaseous condensation to the formation of the solid bodies of the solar system from the earth downward. It appeared that their formation must have been rather radically influenced (1) by inherited motions, (2) by the loss of light material through molecular activity, and (3) by the formation of precipitates and precipitate aggregates. The lines of planetary descent for this class of bodies seems to have lain through Brownian mixtures and precipitate-aggregates. These, supplemented by planetesimal infall, seem to provide working conditions suited to meet the formative requirements of these solid bodies.

9. A study of the aberrant features of the solar system seemed to bring them into harmonious genetic and working relations with the normal features and, so interpreted, they give concurrent and confirmatory testimony.

10. The explosive vulcanism of the moon and also that of the earth furnish cogent reasons for replacing the inherited view that they were once molten globes by an accretional origin better adapted to furnish the essential conditions of explosive action.

11. The convergent testimony of recent observational, experimental, and mathematical investigations on the behavior of rock under stress, on the body tides, on the polar nutation, and on the transmission of seismic waves, points to an increase of density, rigidity, and elasticity graded toward the earth's center in harmony with the natural effects of oscillating stress differences which grow more intense in a similar ratio from surface to center. To bring the whole into harmony, the high mean values of all these increasing physical properties require a consistent extension of the gradation over the ground not yet covered by explicit observation. The conclusions reached by the comparison of the earth with its neighbors and the collateral inquiry into the formative processes give results that are in close accord with the convergent determinations of the several other lines of investigation that are now beginning to throw revolutionary light on the constitution of the earth.

HISTORY.

Fox, Dixon R., Columbia University, New York, N. Y. *Completion of the work of the late Professor H. L. Osgood toward an institutional history of the American Colonies during the period of the French wars.* (For previous reports see Year Books Nos. 11–18.)

Much progress has been made in revising and completing the manuscript of the late Professor Herbert L. Osgood on "The American Colonies in the Eighteenth Century," which will be ready for publication in four volumes about November 1920. Inasmuch as my own work is critical and supplementary, rather than extensively original, no further report here seems necessary. These volumes, continuing the three published in 1904 and 1907, will be in themselves a report of a life-work in the origins of American institutions. Professor Frank W. Pitman, of Yale University, will contribute a chapter on the "West Indies in the Eighteenth Century."

HISTORY OF SCIENCE.

Sarton, George, Cambridge, Massachusetts. *Associate in the History of Science.* (For previous report see Year Book No. 18.)

The general purpose of my efforts was explained in my first report (Year Book No. 18, pp. 347–349). The present report deals with the period extending from July 1919 to the end of August 1920.

My activities will be briefly considered under the following headings: (1) Work in Europe; (2) history of science; (3) Leonardo studies; (4) history of physics in the nineteenth century; (5) the new humanism.

1. *Work in Europe*.—From July 17, 1919, until January 27, 1920, I spent about one month in England, one in Italy, and three in Belgium. In the latter country the hospitality of the Institut de Sociologie Solvay greatly facilitated my work. The aims of my journey, as set forth in my previous report, were accomplished. In particular, meetings with Aldo Mieli in Florence and Charles Singer in Oxford enabled us to discuss the organization of our common studies. The recovery of the greater part of the notes, which I had been obliged to abandon in Belgium in 1914, will enable me to take full advantage of my work done before the war. This will be possible, however, only when all these older materials, which the invaders left in a state of utter disorder, are reclassified and amalgamated with my newer notes.

2. *History of Science*.—Upon the unexpected recovery of my pre-war collections, I resolved to resume at once the accomplishment of an old design, namely, the writing of an introduction to the history and philosophy of science, a sort of compendium of all the sources of information to which the student of the history of science may have to refer.

While in Belgium, I again took up the publication of *Isis* and edited two numbers, 6 and 7 (Vol. II, pages 313–488; Vol. III, pages 1–156). The chief feature of *Isis* is its critical bibliography of the history, philosophy, and organization of science and of the history of civilization. The last two numbers contain the reviews of 42 books and papers, and about 1,150 other publications are briefly analyzed or simply quoted. The first seven issues of *Isis* contain a total of about 144 reviews and 4,546 bibliographical notes. The aim of this bibliography being primarily historical, the fundamental classification is chronological (as much as possible by centuries). From Volume IV onward, Dr. Charles Singer, of Exeter College, Oxford, will become coeditor of *Isis* and will be specially responsible for the biological and medical sciences and the mediæval period, while I will assume responsibility for the rest.[1]

In Volume II of *Isis* I have published a study of the development of geology from 1775 until now, special stress being laid on the work of Eduard Suess. This paper also contains a chronological list of the main geological maps published since 1684.[2]

Upon my return to America, before proceeding to Cambridge, I stayed four months in Washington, D. C., where my time was taken up chiefly by (1) the study of the German publications on the history of science which appeared during the war; (2) the preparation of No. 8

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[1] Sarton, George: Avant-propos, Isis, Vol. II, 313–314, 1919; The publication of Isis, Science vol. 49, 170–171, 1919.

[2] Sarton, George: La synthèse géologique de 1775 à 1918, *Isis*, Vol. II, 357–394, 2 pl., 1919.

of *Isis;* (3) the study of the historical collection of instruments, tools, and machines kept at the National Museum.

3. *Leonardo studies.*—These studies have been temporarily interrupted (1) because while in Italy I heard that the great Galilean scholar Antonio Favaro, of Padova, had almost completed the deciphering of the English codices, a tedious task which it would be wasteful to duplicate. The publication of Favaro's work is delayed only by economic circumstances; (2) because the preparation of my introduction to the history of science is far more urgent. I have examined the Leonardo manuscripts kept at Windsor Castle, at the British Museum, and at the South Kensington Museum, and have made arrangements for their being photographed as soon as this is necessary.

4. *History of physics in the nineteenth century.*—I continue to collect materials on this subject, although I shall not be able to devote myself entirely to it before the Leonardo investigations are completed. I take advantage of this report to ask for the assistance of all persons who may happen to possess biographical information on the physicists of the last century. Such information is often difficult to obtain, as most academic biographies, for instance, are more concerned with artificial data (such as degrees and other honors) than with biographical facts of intrinsic value.

5. *The new humanism.*—I am carrying on my propaganda for this movement—that is, the reconciliation of the scientific with the humanistic spirit, and have written the following papers to support it: War and Civilization (*Isis*, II, 315–21, Bruxelles, 1919); Secret History (*Scribner's Magazine*, vol. 69, p. 187–92, New York, Feb. 1920); Herbert Spencer (*ibidem*, p. 695–702); The Faith of a Humanist (*Isis*, III, 3–6, Bruxelles, 1920). I gave only one lecture, namely, before the Institut des Hautes Études, Université Nouvelle, in Brussels.

The hospitality extended to me by the Widener Library at Cambridge enables me to pursue my work under the best conditions. In exchange I have agreed to give a short course of lectures to the Harvard community.

LITERATURE.

Bergen, Henry, Brooklyn, New York. *Research Associate in Early English Literature.* (For previous reports see Year Books Nos. 11–18.)

Dr. Bergen reports that the entire text of Lydgate's "Fall of Princes" is now in type, and it is hoped that two volumes, containing the text and some introductory matter, will be ready for publication in 1920. Work on the "Troy Book" glossary has gone on, parallel with the issue of each part of the Oxford Dictionary.

Tatlock, John S. P., Stanford University, California. *Preparation of a concordance to Chaucer.* (For previous reports see Year Books Nos. 16–18.)

The slips for the Concordance to the Works of Chaucer, in number about 250,000, have been prepared by about forty volunteer collab-

orators in various parts of the country. Begun in April 1919, they are now all in the hands of the editor, and have been twice verified and otherwise edited by a staff of assistants. Slips for variant readings are being prepared by volunteers and by the editor; also slips for selected examples of words not to be printed in full. Alphabeting is now proceeding rapidly and it is hoped will be completed by the end of the summer of 1920. The chief remaining task will then be adjusting and standardizing the arrangement.

MATHEMATICAL PHYSICS.

Moulton, F. R., University of Chicago, Chicago, Illinois. *Investigations in mathematics, cosmogony, and celestial mechanics.* (For previous reports see Year Books Nos. 5, 6, 8–18.)

During the past year the volume on Periodic Orbits, Publication No. 161, has appeared. A large amount of work was done on the last chapter, pp. 485–524. Three papers on optical subjects have been published in Visual Education (Chicago), as follows:

1. Human eyes, January, pp. 25–34.
2. Telescopes, April, pp. 17–23.
3. Spectroscopes, May, pp. 11–17.

At the American Mathematical Society Colloquium, which was held in Chicago, September 8–11, 1920, five lectures were given on "Topics from the Theory of Functions of Infinitely many Variables." These lectures, which contained a large amount of original mateiial, will be published by the American Mathematical Society. The titles of the lectures and their synopses, as given in the program of the Colloquium are as follows:

I. Infinite Systems of Linear Equations.

1. Completely reduced systems. Historical examples.
2. The formal method of reduced systems. Historical examples.
3. Normal infinite determinants. The Hill-Poincaré form; the von Koch form.
4. Infinite systems of linear equations having normal determinants and bounded right members.
5. Absolutely convergent infinite determinants.
6. Infinite systems of linear equations having absolutely converging determinants and bounded right members.
7. Infinite systems of linear equations having absolutely converging determinants and coefficients analytic functions of a parameter.
8. Irregular solutions of infinite systems of linear equations. Examples.
9. The general theory of Schmidt. Solutions for which

$$\sum_{i=1}^{\infty} |x_i|^p \, (p>1)$$

converges, including the limiting cases $p=1$, $p=\infty$.

10. The methcd of successive approximations.

II. On Properties of Functions of Infinitely Many Variables.

1. Hilbert space (H-space) and parallelopipedon space (P-space). The mutual independence of H-space and P-space.

2. Definitions of limit points. Existence of a limit point in an infinite set of points.
3. Types of continuity and relations among them.
4. Convergent functions and uniformly convergent functions.
5. Independence of continuity and convergence.
6. Representation of convergent functions by series.
7. A continuous function of infinitely many variables in a closed P-space has a maximum and a minimum and all intermediate values.
8. Definition of analytic functions of infinitely many variables.
9. Definition of normal functions of infinitely many variables.
10. Finite operations on functions of infinitely many variables.
11. Limiting processes on functions of infinitely many variables.
12. The mean-value theorem for completely continuous functions having first derivatives.
13. Taylor's theorem for functions of infinitely many variables.

III. INFINITE SYSTEMS OF IMPLICIT FUNCTION EQUATIONS.

1. Analytic solutions of reduced normal equations.
2. Analytic continuation of the solutions.
3. Solutions of normal equations having normal determinants of the coefficients of the linear terms of the dependent variables.
4. Properties of the solutions of normal equations.
5. Solution of reduced normal equations by the method of successive approximations.
6. Extension of the solution to a boundary of the region of definition of the equations.
7. Solutions of infinite systems of equations having continuous first derivatives.
8. Properties of the solutions.
9. Extension of the solution to a boundary of the region of definition of the equations.

IV. INFINITE SYSTEMS OF DIFFERENTIAL EQUATIONS.

1. Analytic solutions of normal equations.
2. Solution of normal equations by the method of successive approximations.
3. Solution of equations satisfying the Lipschitz condition by the method of successive approximations.
4. Properties of the solutions.
5. Extension of the solution to a boundary of the region for which the equations are defined.
6. Solution by the Cauchy-Lipschitz method.
7. Solutions of infinite systems of linear differential equations having constant coefficients.
8. Solutions of infinite systems of linear differential equations having periodic coefficients.

V. APPLICATIONS OF FUNCTIONS OF INFINITELY MANY VARIABLES.

1. Hill's problem of the motion of the lunar perigee.
2. Solutions of linear differential equations in the vicinity of singular points.
3. The determination of the moon's variational orbit.
4. Determination of periodic solutions of certain finite systems of differential equations.
5. The dynamics of a certain type of infinite universe.

A chapter on Numerical Integration of Differential Equations has been written for a volume which is being prepared for the Smithsonian Institution, by Professor E. P. Adams.

MATHEMATICS.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. *Application of Cremona Groups to the solution of algebraic equations.* (For previous reports see Year Books Nos. 9–16.)

Professor Coble has published his memoir on the Ten Nodes of the Rational Sextic and the Cayley Symmetroid (Amer. Jour. Math., vol. 41, No. 4, pp. 243–265, October 1919). He has completed a memoir on Double Binary Forms and the Closure Property, which develops some new points of view and many new instances.

Two other researches of Professor Coble which are in progress may be mentioned: In the first the modular functions of genus 3 are used to obtain a system of irrational invariants of the ternary quartic which can be identified with a similar system arising from the set of seven points in a plane. This connects the rational invariants of the quartic with the invariants of a finite collineation group in 15 variables and would indicate that the complete system of the quartic consists of not more than 17 members.

The second research connects his discovery that the symmetroid can be transformed by Cremona transformations into only a finite number of distinct types with the fact discovered by Schottky that the symmetroid arises from the modular functions of genus 4. Cremona transformations of the symmetroid are induced by the integer linear transformations of the modular functions, when reduced modulo 2.

METEOROLOGY.

Bjerknes, V., Bergen, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics in practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–18.)

In the previous report the following general result was stated:

"The atmosphere is crossed and recrossed by surfaces of discontinuity separating from each other masses of air having more or less different velocity and different physical properties, showing themselves by differences of temperature and humidity, and (as pointed out by Mr. Bergeron) also by marked differences of transparency. Almost every change of weather is due to the passage of a surface of this kind."

On the weather-chart a surface of this kind manifests itself by the line of discontinuity, along which it cuts the ground. Using the detailed weather charts produced for the new Norwegian Weather Service (of the two previous reports), J. Bjerknes, H. Solberg, and T. Bergeron have continued the investigation of these lines. They are seen, from day to day, to sweep over the chart as curves of a more or less wavy form, the waves entering generally at the western and disappearing at the eastern border. Originally the subsequent wave-lines were believed to be independent of each other, but it has become evident that they are connected, forming parts of a single continuous line of

wavy forms. This line is extended all round the pole and there can be no doubt concerning its origin. From the polar regions heavy cold air tends to flow out along the ground, being separated from the overlying warmer air by a surface of discontinuity. This surface has decreasing height as we proceed towards the equator; finally it cuts the ground along a circumpolar line of discontinuity. This line shows how far the cold air has succeeded in penetrating below the warm air. It marks a kind of "polar front."

The waves of this line have a general propagation from west to east. At the same time their form and dimensions change as the consequence of great outbreaks of cold air from the pole and compensating rushes of equatorial air towards the pole. In this way the polar-front line sweeps over the whole of that zone which is called the temperate, and shows in detail how the general atmospheric circulation is conveyed, giving the exchange of air between the equatorial and polar regions.

This result can not fail to exert a considerable influence upon the methods of weather forecasting. The meteorological events of the temperate zone present themselves as details in a large-scale phenomenon—the general atmospheric circulation, with the correlated motions of the polar front. *An effective survey of this front all round the pole will form the rational basis of short-range as well as of long-range weather forecasts.*

The forecasts of the new Norwegian Weather Service are now based principally upon the drawing of that part of the polar-front line which comes within the frame of the chart. Thereby the forecasts, especially of the storms on the very exposed Norwegian coast, have been considerably improved. The fishermen have strongly expressed their satisfaction with them. But the forecasts would acquire a much higher degree of perfection if they could be based upon the complete knowledge of the entire polar front. A circumpolar weather-service, organized by international cooperation, would certainly be a great benefit to all occupations dependent upon the weather, such as gariculture, fishing, and shipping, and perhaps no less than a necessity for the realization of transoceanic air-routes.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3–18.)

Since our last report our scientific staff has suffered a severe loss in the death of Edna L. Ferry, M. S., who became associated with us very early in the course of our nutrition investigations, in the conduct of which she has rendered laborious, faithful, and efficient service. We desire to record our appreciation of her unflagging devotion to the researches in which we have been engaged and to pay a deserved tribute

to the sterling worth of our valued collaborator. Shortly before her final illness Miss Ferry was engaged in the preparation of a somewhat detailed description of the technic of the nutrition experiments which has been followed for some time in our studies. This was done in response to numerous inquiries from workers in other laboratories, who like ourselves have recognized the great usefulness of the white rat as a subject of nutrition investigations. The manuscript is now in press.

The comparative study of barley, oats, rye, and wheat as sources of protein, to which reference was made in the report of 1919, has been continued. Our earlier experiments with these cereals were inconclusive, because the rations included, during a part of the period, a small amount of brewery yeast containing protein, which possibly supplemented the cereal protein so as to increase the rate of growth. In our latest experiments the *entire* cereal grains, finely ground, were fed along with an adequate salt mixture and sufficient butter-fat to supply the fat-soluble vitamine. On the basis of evidence obtained by both ourselves and others, the quantities of the *entire* cereal grains used should supply sufficient water-soluble vitamine. The experiments leave no doubt of the adequacy of the *barley* proteins as a whole in the nutrition of growth, for several of the rats grew to large adult size without any other source of protein than that derived from this cereal. Some of the animals on the higher percentages of barley protein even surpassed the normal rate of growth on ordinary mixed food. With the lower concentration of barley in the food the deficit of protein limited the rate of growth, though even on the lowest percentage not inconsiderable gains were made.

The feeding experiments with pearled barley were not as satisfactory. The growth obtained was relatively slight in comparison with the more adequate gains on foods of a similar calorific nature, containing 8 per cent of protein from the entire barley grain. The addition of vitamine in the form of yeast did not improve the results. It is not unlikely that the milling process has removed fractions of the barley protein residing in the outer layers of the grain, which supplement the less effective proteins of the barley endosperm. In a similar way it is known that the total proteins of wheat are superior to the proteins of the endosperm of that cereal.

In the case of the *oat* kernel the successful growth of several animals to large size indicates that the total protein of the oat kernel furnishes all the essential nitrogenous units if the intake of food and its concentration of protein are adequate. For some reason the animals did not eat the oat foods as readily as the barley rations, a fact which may explain the failure of a considerable number to thrive.

Although several animals grew fairly well for a considerable period on foods containing an adequate percentage of *rye*, they have invariably failed to reach a large size. Had our investigations been con-

fined to a few weeks or months we probably should have failed to realize the exceptionally large mortality which subsequently involved our rye-fed animals. The seemingly good nutrition of the rye-fed animals in the earlier periods of their life makes it unlikely that the proteins *per se* are chargeable with the untoward results subsequently exhibited by this group of animals as a whole. What other deleterious factor, if any, may be present we are as yet unable to state.

In confirmation of earlier experience, we have again demonstrated that growth to large adult size can be completed at a normal rate on a food containing a liberal content of the entire *wheat* kernel. Several litters of young were secured from females on such a diet.

In order to ascertain the comparative value of the total proteins of the individual cereals, we have made a numerical comparison of the gains per gram of protein eaten and calorific intakes during comparable periods. The upshot of this has been to show a comparative equality of the four types of cereal proteins recorded, particularly when the gains which they promote per gram of protein consumed are contrasted with those secured within comparable periods of growth by the use of proteins from other sources. To quote our published report, "we were surprised to find that the efficiency of the entire wheat kernel, as well as that of the other cereal grains studied, without supplementary proteins, was so far superior to that ascertained by us earlier in the study of the endosperm. The utilization data secured by us testify to the unexpected availability for growth of the proteins of these whole cereals."

Early in our studies on the comparative nutritive value of different proteins, the failure of gliadin to permit satisfactory growth was repeatedly demonstrated. On diets in which gliadin is the sole protein, animals grow very slowly for a long time. This result was demonstrated to be due to the comparative deficiency of gliadin in lysine, an indispensable amino acid which apparently can not be synthesized by the animal organism. In order to furnish the essential water-soluble vitamine in these gliadin-feeding experiments, we formerly employed our protein-free milk and later dried yeast, both of which products contribute a small amount of protein to the diet. Since this protein may supplement the gliadin to some extent and thus provide a protein mixture more adequate for growth than is gliadin alone, we have repeated the gliadin-feeding trials, supplying the necessary water-soluble vitamine in the form of a protein-free preparation made from yeast in the way referred to in our report for 1919. The results are different from our earlier ones in that the young animals have not grown at all during a long time. The very small content of lysine in the gliadin evidently suffices for the wear-and-tear needs of the body, but in the quantities eaten did not permit any increment of tissue. This is a good illustration of the usefulness of the concentrated protein-free

vitamine preparation, to the production of which considerable attention has been given during the past two years.

For many years the proportion of protein which the cells of the green leaves contain has been determined by conventional methods and, apparently, in no case has any corresponding quantity of protein been isolated and chemically identified. In consequence there is at present no satisfactory evidence of the nature of the compounds containing a large proportion of the nitrogen in the green leaves of any plant. The highly specialized physiological functions of the leaf justify the expectation that it may contain constituents chemically unlike those found in other parts of the plant or in the cells of animal tissues. How far such constituents belong to types of compounds peculiar to the leaf, or to types already well known, is scarcely known at present. It is highly probable that the leaf is the seat of protein synthesis, as already it is known to be the seat of carbohydrate synthesis. The protein of the leaf may represent the original protein from which all other kinds are formed, either directly or indirectly.

Apart from numerous attempts to apply conventional methods for distinguishing non-protein nitrogen from protein nitrogen in leaves and green plants, little appears to have been done to increase our knowledge of this subject. Botanists have made microscopic studies of leaves and other parts of plants which furnish some facts of interest respecting their protein constituents, but at present these reveal little with regard to their chemistry or value in nutrition. The experience which we have had in the past in studying the proteins of seeds prompted us to make this investigation, which finally showed how most of the proteins can be easily separated from the fresh leaf. Although preparations thus obtained doubtless are mixtures of several individual proteins, they are more suitable for a study of the nutritive value of the total protein furnished by the leaf than would be any single protein contained in this mixture.

Spinach leaves were employed because these contain more nitrogen than do most other leaves, and also because a fresh supply can be obtained throughout the greater part of the year. When the walls of the cell are broken by grinding, its contents are liberated and a mixture of the nuclei, chloroplasts, cytoplasm, sap, débris of cell-walls, etc., is obtained. The parts contributing to this mixture are no longer in the same relation to one another as when intact within the living cell; they form an amorphous mixture, in which the components no longer can be recognized under the microscope. When this mixture is diluted with one or two volumes of water and either centrifuged at high speed or passed through coarse filter-paper, an opaque green, slightly viscid fluid is obtained and also a residue, consisting chiefly of the cell-walls. Although the fluid part is very opaque and looks as if it contained much suspended solids, microscopic examination reveals nothing except ex-

tremely minute granules and somewhat larger spherical particles of insoluble matter. Only occasionally can a fragment of the disintegrated chloroplasts be seen. Apparently the fluid passing the filter contains practically nothing except the soluble and the amorphous, colloidal constituents of the cell contents. If the grinding is thorough enough the filtered fluid may contain all the contents of the cells, while the solids retained by the paper are seen to consist only of the walls of the cells and the various ducts.

Addition of alcohol equivalent to one-fifth of this filtered mixture produces a bulky dark-green precipitate which separates, leaving a green, slightly turbid solution. After separating this precipitate with the centrifuge, the further addition of alcohol to one-third of the volume of the original extract yields another large green precipitate and a solution which can be easily filtered clear. On washing these green precipitates with strong alcohol, chlorophyll and other substances are easily removed, leaving an almost colorless residue. When this is treated with ether a deep yellow extract is obtained which on evaporation leaves a semi-solid, fatty residue. The precipitates thus washed when air-dry are nearly colorless, friable products containing about 14 per cent of nitrogen, calculated ash-free.

A considerable part of the first precipitate is not soluble at room temperature either in an aqueous or in a 60 per cent alcoholic solution containing 0.2 to 0.3 per cent sodium hydroxide, although such solutions readily dissolve most types of proteins. If, however, the temperature of such an alcoholic solution is raised to boiling, nearly all this precipitate dissolves. When the resulting solution is neutralized with acid, most of the dissolved substance is precipitated and is then readily soluble at room temperature in a very slight excess of either acid or alkali. The second precipitate, which we call the "colloidal protein" is almost completely soluble in cold, dilute aqueous alkalies.

At least 40 per cent of the total spinach nitrogen belongs to this colloidal protein, about one-third to substances which are soluble in water, and a comparatively small part of the other fourth of the nitrogen belongs to chlorophyll, phosphatides, etc., soluble in strong alcohol, and presumably a part of the remainder to nucleic acid.

Since this colloidal protein is so readily precipitated by a relatively small proportion of alcohol, while at the same time most of the chlorophyll, phosphatides, etc., which were previously insoluble in pure ether, become soluble therein, it seems possible that within the cell these and possibly other substances exist in chemical union as a complex which forms a colloidal solution extremely sensitive to the action of alcohol. If this is so, the solubility and other properties of the constituents of this complex give no idea of their chemical or physical properties as they are combined within the cell.

The residue of the cell-walls, etc., contained about 16 per cent of the total nitrogen of the leaves. Evidence was obtained that most of the nitrogen in this residue of the cell-walls, etc., belonged to constituents of unruptured cells, or of those from which the contents had not been completely removed, and was consequently protein nitrogen. As a result of this investigation it was found that about one-fourth of the solids of the spinach leaf is protein and that one-fourth of its total nitrogen belongs to non-protein substances soluble in water.

The dry solids of the spinach leaf are much richer in protein than are any of the cereals, or, in fact, some of the commercial protein concentrates, such as bran, middlings, etc. If we remember that the cells of leaves are physiologically among the most active that we know, it should not surprise us to discover that the chemical constitution of their contents is much like that of the cells of active animal tissues.

Since many green foods, such as alfalfa or clover, consist chiefly of leaves and when dried and cured are fed as hay, it seemed desirable to examine the spinach leaves after they had been dried in a current of warm air below 60 and to compare the results obtained with those yielded by the green fresh leaves.

The proportion of substances soluble in water is a little greater in the dried leaf than in the green, both protein and non-protein substances contributing to this small excess. The distinctly greater amount of proteose found in the extract of the dried leaf compared with the fresh indicates a slight autolysis during drying, but proof that such a change actually occurs can be secured only by comparing the results obtained with parts of the same sample.

The percentage of the non-protein organic substances extracted from the dried leaves with water is the same as that remaining in solution after precipitating the turbid extract of the green leaves by the addition of one-third volume of alcohol. In both cases the percentage of the total nitrogen soluble in water also is the same. The amount of the colloidal protein obtained from these two sources was likewise nearly the same; hence the results of this comparison justify the conclusion that data obtained with leaves carefully dried at a low temperature closely represent the composition of the leaf in its fresh green condition.

Dilute alcohol precipitates 43.5 per cent of the spinach nitrogen from the colloidal solution obtained by grinding the fresh leaves with water, and most of this is protein nitrogen. The residue of cell-walls, etc., still contained nitrogen equal to 15.2 per cent of the total nitrogen of the leaf, which for the most part is almost certainly protein nitrogen. As there is good reason to believe that most of this belongs to proteins of the same character as those found in the extract, we shall not go far wrong in assuming that in the fresh leaves at least 58 per cent

of the spinach nitrogen, or 21.2 per cent of the spinach solids, belongs to this protein.

The protein extracted from the dried leaves by alkaline alcohol, and which is unquestionably the same as that precipitated from the aqueous extracts of the fresh leaves by the addition of alcohol, contained a little smaller proportion of the total spinach nitrogen than did the colloidal protein obtained from the water extract of the fresh leaves, but this deficit was made up by a correspondingly larger proportion of water-soluble proteins, possibly formed by autolysis during drying.

We have not taken into account its possible contamination with insoluble non-protein nitrogenous compounds. Doubtless the nuclei of the cells contain nucleic acid, but either the amount of this is so small, or else its properties are so different from the nucleic acids with which we have been familiar, as to yield negative results with such tests as were employed. Assuming that the undetected non-protein nitrogenous substances contain too small a proportion of the spinach nitrogen to have importance for this preliminary investigation, we can state the proportion of the spinach nitrogen among the various groups as given below:

	Nitrogen.	
	Fresh leaves.	Dry leaves.
	p. ct.	*p. ct.*
Soluble in ether and alcohol.....	2.3	2.3
Soluble in water:		
Non-protein substances.....	25.9	26.4
Proteose..................	4.8	11.3
Coagulable protein.........	3.8	5.9
Insoluble in water:		
Colloidal protein...........	58.7	53.8
Total..................	95.5	99.7

Stated in terms of percentage of the dry solids of the spinach leaf, the proportions of the different proteins ($N \times 6.25$) obtained from the fresh and dry leaves respectively were as follows:

	Nitrogen.	
	Fresh leaves.	Dry leaves.
	p. ct.	*p. ct.*
Proteose......................	1.7	3.3
Coagulable protein............	1.4	1.7
Colloidal protein..............	21.2	22.8
Total protein............	24.3	27.8

It thus appears that protein substances contain practically two-thirds of the nitrogen in each case. While these figures must be accepted as only roughly approximate, we believe they afford a better basis for assuming that the greater part of the nitrogen of the leaf actually belongs to protein substances than has heretofore been presented.

By applying the results of this investigation to spinach leaves, we have made a protein concentrate which we are now feeding to albino rats. These experiments already indicate that the spinach-leaf proteins, for example, are adequate to supply the nitrogenous needs of an animal during the entire period of growth. This fact, coupled with the demonstration that the leaves are comparatively rich in protein material, emphasizes in a new way the importance of the green fodders as sources of nutriment, particularly when it is recalled that they are rich also in water-soluble and fat-soluble vitamines. Similar products are now being made from other green leaves.

Direct *chemical* evidence has never been obtained that the ammonia which proteins yield when hydrolyzed arises from an amide combination with one of the carboxyl groups of the dibasic glutaminic and aspartic acids. If this assumption, which has generally been accepted as probably the case, is correct, carboxyl groups should be liberated by hydrolysis in a proportion corresponding to the amount of ammonia produced. By a recently completed study we have shown this to be true; consequently there is now little doubt that the ammonia nitrogen is present in the protein in the grouping $R\text{-}CONH_2$.

One object of this work was to learn how to make a protein preparation free from amide nitrogen, so that it could be fed to animals under conditions which would determine whether or not this nitrogen has any value in nutrition. As a result of our investigation we now hope to be able to succeed in doing this. In connection with this work it was necessary to study the early stages of hydrolysis of two proteins, gliadin and edestin, which represent types of markedly different chemical constitution. It is possible that what we have thus learned may help to gain a further insight into the structure of the protein molecule.

Fresh fruits have long been used for the prevention of scurvy, yet almost no experimental data have been available with respect to the distribution of the vitamines in them. We have, therefore, undertaken a series of experiments to test the possible presence of water-soluble vitamine in some of the more common fruits. The fresh juices of the orange, lemon, and grapefruit have been found to contain water-soluble (B) vitamine. Their potency in this respect is quite similar to that of comparable volumes of cow's milk. The efficiency of these fruit juices is not lost by suitable modes of desiccation. A sample of grape juice tested was less potent than equal volumes of the fruit juices just mentioned. The edible portions of apples and

pears furnish some water-soluble vitamine; the quantity of these fruits necessary to supply this dietary essential is relatively very large, so that from a comparative standpoint they can not be regarded as rich in this food factor. Prunes apparently are somewhat richer in the water-soluble vitamine.

From preliminary experiments it seems doubtful whether the juices of the lemon or grapefruit contain more than traces, if any, of the fat-soluble vitamine. Our observations upon orange juice, however, are indicative of some potency in this vitamine.

The experiments with fruits place the dietary value of these foods, hitherto recommended because of their salt content, their laxative properties, or their antiscorbutic potency, in a new light as sources of water-soluble vitamine.

Our earlier investigations on the water-soluble vitamine content of fresh milk were carried out during the winter season, when the cows in this region are deprived of green pasture and are stall-fed. It seemed not impossible that the relatively large quantity of milk necessitated as a source of water-soluble vitamine in those experiments might be associated with quality of milk inferior from the vitamine standpoint, owing to the winter diet of the cows. Consequently, we have undertaken a further series of experiments in which varying quantities of unpasteurized milk, obtained fresh from cows known to be feeding in open pasture, furnished young rats with the sole source of water-soluble vitamine. The outcome has been the same as that of the earlier experiments. With additions of 2 c. c. of summer milk no permanent gains were secured. Additions of 5 c. c. invariably produced better, though by no means adequate, growth; nor was the latter usually obtained with daily additions of 10 c. c. of summer milk. Whenever the vitamine supplement in the form of milk was still further increased, improvement in the rate of growth occurred. The inferiority of even 15 c. c. of the fresh, unpasteurized summer milk as a source of water-soluble vitamine, in contrast with 0.2 gm. of dried brewery yeast, was indicated by the more rapid gains made by all the animals thus tested when the yeast addendum replaced the milk. Even 15 c. c. of the summer milk fed from the start barely sufficed as a source of water-soluble vitamine to promote growth at a normal rate.

Incidentally an opportunity has been afforded during the past year to make a few feeding experiments with human milk with a view to testing its potency as a source of water-soluble vitamine. From the very limited data thus far secured there is no evidence of a greater content of this food factor in this important nutrient than in cow's milk. More extensive investigations of the vitamine properties of *human* milk are desirable.

The study of the relative content of water-soluble vitamine in the various vegetable products has been continued. In these experiments

alfalfa and clover surpassed all the other nine products tested in equal doses of dried material as sole sources of water-soluble vitamine; 1 gm. per day promoted far better growth than we have ever secured with even 16 c. c. per day of milk, containing 2 gm. of solids, fed as a source of water-soluble vitamine in addition to the same basal ration; 0.5 gm. per day of dry alfalfa or clover is not equally efficient. Tomato is rich in water-soluble vitamine. Even 0.2-gm. quantities occasionally promoted limited growth. Doses of spinach, cabbage, turnip, and carrot of 1 gm. did not surpass 0.5-gm. quantities of alfalfa and clover in the results attained, whereas with smaller amounts growth was not maintained. The beet root did not equal the other roots tested. The timothy hay, though potent in the earlier periods of the experiments, proved disappointing in the long run. The potato proved to be as rich in water-soluble vitamine as some of the roots tested, although similar quantities of alfalfa, clover, or tomato promoted more rapid growth. Compared in 1-gm. daily doses, there was little advantage in potato retaining the outer layers over peeled potato of the same age. Dried potato peel was no richer in the vitamine than corresponding quantities of whole potato. Even 2-gm. daily doses of peeled potato did not promote growth at the normal rate. Comparative tests with old and new potatoes have not given indications of any noteworthy differences in content of the water-soluble vitamine.

Until quite recently the importance of plant tissues as carriers of the fat-soluble vitamine has received little recognition in the study of nutrition. Following the demonstration of the occurrence of this food factor in a number of green foods and other vegetable products, we have made a study of the quantities of these carriers of fat-soluble vitamine which serve to keep growing rats in health and vigor when all the other known essential food-factors are supplied. On the basal food mixture employed by us, rats fail to grow after about 40 to 80 days and then begin to decline rapidly in body-weight. Under such circumstances, unless the physiological damage has proceeded too far, restoration of growth and well-being is usually readily brought about by inclusion of butter-fat in place of part of the lard in the food mixture. The characteristic eye conditions or symptoms, sometimes termed xerophthalmia, or perhaps better keratomalacia, which often develop during the decline in health, are speedily relieved when the nutritive conditions begin to improve.

The various plant products dried at a comparatively low temperature were fed as sources of fat-soluble vitamine apart from the food mixture in daily doses of approximately 0.1 gm. of dried substance. For comparison, a group of animals daily received 0.1 gm. of butter-fat, as this product has been already demonstrated to be especially rich in the fat-soluble vitamine. With this comparatively small intake of the latter, the animals receiving the butter-fat reached maximum

weights of approximately 300 gm. before giving any indication of qualitative inadequacy of their diet. Some of the dried plant products were quite as efficacious in supplying the needed fat-soluble vitamine. This was true for the alfalfa, clover, grasses, spinach, and carrot. Cabbage was less satisfactory in these small quantities, and in the case of potato large amounts were necessary to furnish a quantity of fat-soluble vitamine sufficient to promote growth for even a limited period. The tomato was unique in its efficiency. The latter vegetable has now been demonstrated to furnish all three at present recognized types of vitamine in considerable concentration and to retain its properties even after desiccation.

Our observations on the occurrence of fat-soluble vitamine in the dried plant-tissues indicate, contrary to the assumption of some investigators, that mild heating and desiccation do not necessarily deteriorate the fat-soluble vitamine in the fresh foods. This now abundantly verified fact is important in connection with the present-day attempts to conserve by desiccation all the essential properties of many natural foods.

In summarizing our studies of the past year, together with those of other recent investigators, we have remarked that they indicate the richness of many types of plant tissues in those nutritive properties termed vitamines and place the dietary importance of the green vegetables in an entirely new light. They further show that the fat-soluble vitamine need not be sought solely in foods known to be rich in fats. The use of vegetables and fruits is thus emphasized, as supplements to the refined products of the modern food industry, which are rich in proteins, fats, and carbohydrates, but in many cases comparatively deficient in the vitamines.

In the report for 1919 attention was directed to attempts to prepare rations as free as possible from the water-soluble vitamine. We have since directed our efforts to preparing diets free likewise from the fat-soluble vitamine. The results of these still incomplete experiments indicate that a preliminary treatment with alcohol and subsequent long-continued extraction with ether containing both alcohol and water removes the fat-soluble vitamine from proteins, starch, and yeast more completely than does extraction with pure anhydrous ether alone, in so far as one can judge by the time which elapses before growing animals show characteristic failures of growth on diets thus treated.

There is much to suggest that the fat-soluble vitamine is combined in the tissues in some way analogous to the phosphatide-protein compounds which are known to exist and from which the phosphatide is not extracted by ether until it has been liberated by preliminary treatment with alcohol. However, our young animals, on diets as free from the fat-soluble vitamine as we have thus been able to make them, grew

for a longer period than many published researches have led us to expect. This is in harmony with some of our earlier experiences before the role of the vitamines was as well known as at present, and likewise with the belief of some of the English investigators, who note that "the animal organism normally contains reserve supplies of the factor A in its own body," and that "these reserves are mobilized for use when a deficiency occurs in the diet, but as soon as they are exhausted growth is immediately inhibited." It is possible that, as McCollum has suggested, this difference in the time of survival can be attributed to the animals rather than to the diets, our rats being perhaps more vigorous than many of those used by others.

At the present time uncertainty prevails regarding the effect of heat upon the various vitamines. We have repeatedly pointed out that heat as applied in the ordinary process of desiccation or cooking does not noticeably affect the water-soluble vitamine. Our experience with the fat-soluble vitamine has not been in harmony with that of certain other investigators who regard this food-factor as very *readily* destroyed by heat. In view of the importance of the matter, we are repeating these studies. Experiments still in progress have confirmed our former experience respecting the failure of steam to affect the potency of butter-fat as a source of the fat-soluble vitamine. These have also shown that even heating in a dry oven at 100° C. for as long as 16 hours does not greatly affect the efficiency of butter-fat in restoring animals that are suffering from the effects of the lack of the fat-soluble vitamine in their diet. We are not yet in a position to assert that heat has no destructive action; but whatever, if any, may occur is certainly not great. Why this food-factor has shown greater stability in our hands than in that of other investigators we are not yet prepared to explain. The most striking illustration of heat stability which we can report at this time involves the at least temporary relief of animals with daily doses of 0.1 gm. of butter-fat heated at 110° for 16 hours. Proceeding on the assumption of others that prolonged heating in an oven will destroy the fat-soluble vitamine, we have tested foods subjected to dry heating at 93° for 15 hours without noting any striking deterioration.

Practical feeding is concerned with the naturally occurring foods, and for these many of our experiments have given some indication of relative values. From the more purely scientific standpoint it is desirable to know whether the need for the various vitamines is related to the amount of active tissue, *i. e.*, to the extent or intensity of the metabolism, to the size and age of the animal, and whether these needs vary absolutely or relatively under a variety of physiological conditions. Accordingly we have begun a study of the minimum quantities of brewery yeast required by animals of varying sizes and stages of growth to develop normally.

In attempting to ascertain the relative physiological need of water-soluble and fat-soluble vitamine respectively, we have undertaken experiments in which the animals have been deprived of both factors simultaneously. Under these conditions restoration of nutrition will under no circumstances occur unless the water-soluble factor at least is supplied. The rate of decline and the length of life is not essentially different in the case of animals deprived of both vitamines than in those which are offered a supply of every other known essential factor except the water-soluble vitamine. The relatively greater immediate importance of the water-soluble vitamine for nutritive well-being applies to adults as well as to young animals, whereas our still unpublished experiments on the need of the fat-soluble vitamine at different ages indicate that that need is most manifest during the growing-period.

Inasmuch as small quantities of green leaves, which are relatively very poor in fats, can serve as adequate sources of fat-soluble vitamine, it has become possible to construct dietaries which contain no fat other than the insignificant quantity present, for example, in 0.2 to 0.4 gm. dried alfalfa, which supplies the essential fat-soluble vitamine. Thus for the first time it is possible to determine whether fat *per se* is necessary for nutrition. Furthermore, the type of fat or fatty-acid component of the diet may be modified within very wide limits independently of all other essential factors in the ration. Likewise, it is now possible to study the behavior of diets devoid either of all carbohydrate or of specific types of the latter, such as starch, etc. Experiments in this field are being conducted by us.

PALÆOGRAPHY.

Lowe, E. A., Oxford, England. *Associate in palæography.* (For previous reports see Year Books 9–16.)

The unfortunate effects of the interruption caused by the war are gradually being overcome. Cooperation with scholars in other lands is slowly being reestablished, and plans for publication cut short by the war are once more being matured. While this is of importance to all scholars, it is particularly so to one whose researches make him dependent upon collections scattered throughout the entire continent of Europe.

The autumn and winter months were spent in planning and gathering material for a comprehensive work on the Anglo-Saxon script which will form the main object of investigation for the next few years. The greatest difficulty confronting one to-day is the high cost of photographs and facsimiles which constitute the raw material of one's investigations. During the spring two visits were made to the famous Phillipps collection of manuscripts in Cheltenham, where all the oldest manuscripts were examined and a careful study made of the best manu-

script of Apicius hitherto unused. The collation made of this manuscript will be used in the forthcoming Teubner edition of Apicius, and a short description of the manuscript has appeared in the "Berliner Philologische Wochenschrift." An article on the unique manuscript of Apuleius's "Metamorphoses" appeared in "Classical Quarterly." The delayed edition of the "Bobbio Missal" with palæographical notes was published during the year. The Pliny Study has been amended and a translation has been added. It is hoped that it will see the light in the coming year.

PALÆONTOLOGY.

Case, E. C., University of Michigan, Ann Arbor, Michigan. *Study of the vertebrate fauna and palæogeography of North America in the Permian period, with especial reference to world relations.* (For previous reports see Year Books Nos. 2, 4, 8–18.)

Work has continued through the year in gathering and compiling material in preparation of a report upon the stratigraphy and palæogeography of the Permo-carboniferous and Permian of the world in relation to the deposits of the same age in North America.

A trip was made into the Triassic beds of western Texas in the hope of establishing some relationship between the Permo-carboniferous and Triassic. The beds were found to be upper Triassic, and a considerable collection was made from a new locality. This collection is not yet worked up, but includes several new forms, notably a new suborder of phytosauroid reptiles. A preliminary description has been published in the Journal of Geology (vol. 23, No. 6, 1920).

Hay, Oliver P., U. S. National Museum, Washington, District of Columbia. *Associate in Palæontology.* (For previous reports see Year Books Nos. 11–18.)

The greater part of the time since September 1919 has been devoted to the study of the Pleistocene deposits and of the Pleistocene vertebrates of the States west of the Great Lakes: Wisconsin, Minnesota, North Dakota, South Dakota, Montana, Wyoming, Idaho, Washington, and Oregon. Those parts of these States which lie north of the Missouri River are covered mostly by glacial drift of Wisconsin age. In these glaciated regions few vertebrate fossils have yet been discovered, and most of these belong to post-Wisconsin times. They are mostly elephants, mastodons, and musk oxen. The subject becomes more interesting in Idaho, Oregon, and Washington. A considerable number of collections have at different times been made in these States and many species have been discovered. Usually, too, these species are those which lived during the early Pleistocene.

Along Snake River, stretching in a great curve from near Yellowstone National Park into Oregon, are the Snake River Plains. A description of these, with a map, was presented by Dr. I. C. Russell in 1902 (Bull.

No. 199, U. S. Geol. Surv.). Formerly a great lake, in some places more than 100 miles wide, occupied the valley and continued on until late Pliocene time and even into the Pleistocene. Toward the end of its existence vast sheets of lava were poured over the accumulated deposits of sand and gravel. On Russell's map somewhat more than the upper half of the valley is marked as covered with lava; the lower half is represented as occupied by Tertiary lake-beds; but in these are also intercalated lava-sheets. These lake-beds have been referred by geologists and palæontologists to the Pliocene.

In 1883 Cope described from these upper lake deposits numerous species of extinct fishes; and he gave the beds the name Idaho formation, referring it to the Pliocene. He called attention to the fact that these beds had furnished also remains of mastodon (*Stegomastodon mirificus*), a horse, and a megalonyx. Since then Dr. John C. Merriam has reported from apparently the same deposits a new saber-tooth tiger, a new antelope, a new horse, and a rhinoceros. At various places in the upper half of the valley the writer has evidences of the discovery of horses, camels, *Elephas columbi*, *E. imperator*, and bisons. In several cases these have come from deposits underlying sheets of lava. They belong at latest to the first interglacial (Aftonian), and probably to the Idaho formation.

Other discoveries of animals recognized to be of Pleistocene age in apparent association with genera otherwise known only from the Pliocene have been made in Florida and Oregon. In such cases it has been assumed that there has occurred, either before or after exhumation, a commingling of faunas of two different ages. From a small cave in Coconino county, Arizona, the writer has studied a collection containing many animals, among them horses, which are of common occurrence in the Pleistocene; but with them come two species of camels of the genus *Procamelus*. These are closely related to two species found in Florida mingled with Pleistocene animals, but they have been referred to the lower Pliocene or even the upper Miocene. No mingling of faunas had occurred in the Arizona cave, and it now becomes probable that none had occurred in the other cases referred to. The writer believes, therefore, that the vertebrates of the Arizona cave, of the Idaho formation, and not unlikely those of the Florida and Oregon localities, all belong to the Pleistocene, but to an older Pleistocene than the Aftonian. It seems necessary to refer this older fauna to the oldest Pleistocene, that corresponding to the first interglacial stage. Nothing about this fauna has hitherto been known.

Further evidences have been received during the year that the lowest lands along the Gulf of Mexico have undergone little or no submergence since the early Pleistocene. Remains of an *Elephas columbi,* of a species of *Gomphotherium,* and of a camel have been found in Texas at the edge of salt water and buried only a few feet above sea-level.

Besides completing the study of the collections mentioned in the preceding report, the results of which appear in the Proceedings of the United States National Museum, the writer has studied the interesting collection made in Arizona and a small collection made in Oregon. All the collections referred to have yielded new species. The range of the hairy mammoth, *Elephas primigenius*, has been extended into Tennessee and into Texas near San Antonio.

Wieland, G. R., Yale University, New Haven, Connecticut. *Associate in palæontology.* (For previous reports see Year Books Nos. 2–4, 6–9, 11–18.)

In earlier reports, especially those for the years 1917-1919, the scope of the palæontologic investigations centering about the cycadeoids, their relatives, and their derivatives, is briefly brought into view. It should be emphasized, however, that throughout the entire course of these studies, now extending over a period of 20 years, a great aim has been to secure new material afield, affording evidence of the origins of seed plants. The zoologist, the botanist, the ecologist finds at his feet vast categories of fact requiring the correlations that make new discoveries a certainty. The assemblage of most biologic data thus goes on rapidly, and usually the picture is complete, whatever the interpretation. But fossil plants are brought together slowly, only as the horizons which yield them are searched with renewed care. Then, between the more striking "finds," laboratory examination and comparative studies are pushed towards the limits of the evidence in hand. Fortunately, the actual evidence secured is not always meager. As noted last year, the coniferous stem material now accumulating is much in advance of present laboratory study.

In the case of the gymnosperm imprints and casts, the greatest need is for prolonged search of Triassic and Jurassic fresh-water terranes. It is now evident that the lower half of the Mesozoic holds the transition forms between the gymnosperms and early dicotyls; and, as already insistently pointed out, it is also pretty certain that, with the plastic types neither few nor obscure, the course of change from period to period goes on in entire floras, resulting in a certain prevailing cast of plant life, or simply those successive stages of development already more or less in view, but not well understood because of the dearth of intermediate types.

The outstanding result of the cycad studies has not been so much the demonstration of floral organization in a few forms (about a score). It is rather that broader study, which has in some adequate measure brought out the real nature of the cycadeoid cast of Mesozoic vegetation, so that it is now possible to see that the cycadeoids are not specialized as hitherto believed, but of generalized floral, leaf, and stem type, and that they must have dominated not merely in numbers, but

in the structural and plastic sense; and so far has this general result been pushed that to-day the value of gymnosperm leaf species in our conceptions of past change is perhaps fourfold what it was when these investigations were begun. A point has been reached where the discovery of the structure of a single antecedent dicotyl stem of the early Jurassic would be of momentous importance.

Primarily the fossil plants afford a much-broken record of descent and of past distribution. They are a chief index of former climates; and, very distinctly through the work of Clements, the data of palæcology come into view. In the newer and broader field the facts of both the animal and the plant record must constitute a well-founded palæobiology. Perhaps the manner in which this fossil evidence solves or promises to solve abstruse problems which botanists alone are hardly in a position to attack may be simply illustrated by asking the question whether the great size of magnolia flowers, or of the cones of certain conifers and cycads, is primitive or not. Evolutionists would like to know. This question is really of crucial importance. Now, the fossil evidence so far found at least shows that it will not do to rest content with interpreting the flowers of a form like the *Magnolia campbelli* or the huge cones of *Pinus coulteri* as mere examples of gigantism. The cycadeoid flowers show that great cycles of reduction in organs of fructification are a possibility to be reckoned with, and further discoveries indicating the trends of past floral changes in the simple feature of bulk and seed output are eagerly awaited.

This year has been given to general field work in Mesozoic and Tertiary "bad lands" areas east of the Rockies as a member of Dr. Clements's party, to some special field work in Wyoming, to some general observation of the living and fossil conifers of California and Arizona, and to work on manuscripts, without any major subject being brought near to publication.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. *Continuation of investigations in interferometry.* (For previous reports see Year Books Nos. 4, 5, 7–18.)

During the year, Professor Barus has been occupied with application of interferometry to a variety of gravitational experiments. The main features of the first group of these have already been communicated (Science, vol. 50, pp. 214, 279; Proc. Nat. Acad. Sci., vol. 5, p. 547, 1919). They relate to the motion of a gravitation needle in a viscous medium like air, to the possible determination of the Newtonian constant in terms of the viscosity of air, to the remarkable pervasiveness of radiant forces arising in temperature changes of the environment, to the behavior of the needle in a vacuum, etc.

In another group of experiments, methods were tested as to the degree with which they might suffice to determine the acceleration of gravity when a fixed installation is not assured. In the first set, this constant was referred to the torsion of a steel wire, the readings being made by the interferometer with an accuracy of 1 part in 100,000. It was found that the viscosity of the wire could be adequately allowed for, but that the thermal coefficients, both of rigidity and of viscosity, are so large, relatively, as to make the reductions untrustworthy unless metals of small thermo-elastic changes like the Guillaume alloys are used. The experiments are still in progress. In the second set of experiments (also in progress) the acceleration of gravity was expressed in terms of the pressure of the air imprisoned in a Cartesian diver when floating at a given level. The limit of accuracy here should be about 1 part in 10,000. Again, however, changes of temperature produce a relatively enormous error, inasmuch as the air is dissolved or released by the water envelope in a way that admits of no adequate control. Only by keeping such an instrument in a thermostat could interpretable results be obtained. The experiments have been continued throughout several months, both under constant and under variable temperature conditions; for it seemed that an apparatus for the purpose in question, which admits of rough handling, of use on board ship, for instance, should not be hastily abandoned.

Hayford, John F., Northwestern University, Evanston, Illinois. *Investigation of the laws of evaporation and stream flow.* (For previous reports see Year Books Nos. 12–16.)

As stated in the original application for the grant under which this investigation is being made, "the ultimate object is to obtain a much better formulation than the engineering profession now has of the laws governing the amount of the stream flow." It appeared probable that progress toward this end is conditioned upon first securing a better knowledge than is now available of the laws of evaporation from large water surfaces and land surfaces. Hence, the immediate object of the investigation was stated to be "to determine the laws of evaporation from a large water surface with much greater accuracy than they are now known." For this purpose it was proposed to consider each of the Great Lakes in turn as an evaporation pan and to evaluate the change of content, the income, and the outgo, including evaporation. As the investigation progressed, it soon became evident that it is necessary to determine the effects of barometric changes, and of winds, in disturbing the daily level of the lake at each recording gage which is used to determine the elevation of the lake surface for the day. The total content is known if the elevation of the mean surface of the lake is known. Still later, it became apparent that it is necessary

to determine the hourly disturbance of level at each gage by the wind, the fluctuations in level due to the wind having been found to be of such a character that a consideration of mean daily values of elevations and of the wind directions and velocities is not sufficient. These successively discovered difficulties must apparently be overcome in the following order to secure a better formulation of the laws governing the amount of stream flow: (*a*) The response of the water surface at a recording gage, hour by hour, to winds of varying directions and velocities must be determined. (*b*) The fluctuation of the level at the gage from day to day, due to both the winds and the barometric gradients, must be evaluated. (*c*) The evaporation from the lake surface under the various conditions must be determined with all the accuracy possible. When this full-scale determination of the laws of evaporation from a large water surface becomes available it is probable that progress on the stream-flow investigation can be made.

The investigation had progressed to the stage indicated by the general statement of the preceding paragraph in August 1916.

During June, July, and August 1920 the investigation has been concentrated on the hourly wind effects. Decided progress has been made. Nearly complete determinations have been secured at Buffalo and Cleveland on Lake Erie. The success in this respect has shown that this part of the problem can, with reasonable promptness, be conquered for each station sufficiently to make the way clear thereafter for rapid and continuous progress on the main problem of determining the evaporation. It is now clear that the process of computing the evaporation can be greatly simplified and shortened in comparison with that originally contemplated. It appears, therefore, that the month of July 1920 has marked the change in the investigation from the stage of successive discovery of new difficulties and complexities to a stage, which it is hoped will last to the end, of steady progress along a reasonably clear road. It is believed that the principal difficulties and complexities are now known and that effective methods have been developed for overcoming them.

An intensive study is nearly complete of the record of hourly elevations of water surface on 22 days each at Buffalo and Cleveland. The principal points of interest and importance are indicated briefly in the paragraphs which follow. It is fitting that the detailed statement of these points be reserved until the study is complete and has been strengthened and confirmed by a similar study at three points on Lake Michigan-Huron.

The response of the lake surface to each change of wind is very prompt. The lag is a few minutes only, certainly less than one hour. Whenever the wind over any part of the lake changes in direction or velocity, a corresponding change in the slope of the water surface in

that locality occurs within a few minutes. The slope of the water surface produced by the wind is, of course, upward to leeward.

The slopes produced by the winds at a given point on a lake are proportional to the 2.4 powers of the wind velocities. In other words, if a wind of 10 miles per hour, from the west, produces at a given point on the lake an upward slope to the eastward of x feet vertical per 1,000 horizontal, a west wind at 20 miles per hour will produce a slope upward to the eastward of $5x$ feet per 1,000, and one of 50 miles per hour will produce one of $48x$ feet per 1,000. The 2.4 powers of 10, 20, and 50 are respectively 251, 1,326, and 11,954. The ratio of the second to the first is 5 to 1, and of the third to the first is 48 to 1. In forming a physical conception of the action, it is important to note that the slope increases with increase of wind velocity much more rapidly between 20 and 50 miles per hour than between 10 and 20. The exponent 2.4 has been determined with a moderate degree of accuracy only. The final value may prove to be 2.3 or 2.5.

When a wind of uniform velocity and fixed direction is blowing, and is the same at all points on a lake, the slope produced at each point of the lake surface is primarily a function of the depth at that point, and to a limited extent of the depths at the other points and of the shape of the shore. The disturbance of elevation of the water surface at any point is a complicated function of all of the depths in the lake and of the location of the shore-line. A method has been developed which will take this complicated function into account and enable one to compute the disturbance of elevation at any given point on the lake surface produced by a wind from any given direction and of unit velocity. Let the numerical value of this function be called Σ. Then the disturbance of elevation at a given point produced by any wind is

$$(h^{2.4})\ (\Sigma)\ (C)$$

in which h is the wind velocity and C is an arbitrary constant to be determined from the observed fluctuating values of winds and water elevations. C has been determined with a moderate degree of accuracy from the observations at Buffalo and Cleveland. The value of C will soon be determined somewhat more accurately, when the computations for Buffalo and Cleveland are complete. The accuracy will be still further increased by similar computations based on observations at Milwaukee, Mackinaw City, and Harbor Beach on Lake Michigan-Huron.

If the constants and the formula just considered were applicable only to the points treated on the Great Lakes, their value would be limited to use in this evaporation investigation. But the function Σ is based on well-established hydraulic principles which are applicable everywhere. It is primarily based on the Chezy formula, connecting

the velocity of a current with the slope of the water surface and the dimensions of the channel in which the current is flowing. The values of the exponent (about 2.4) and of C are both determined by observations in such wise that they are constants of general application anywhere in the world on any free water surface, on any lake, on the open ocean, or on any gulf, bay, or river. The outcome of this part of the investigation is a method of computation and the necessary fundamental constants for use in it, which will enable one to compute the disturbance of elevation produced at any point on a free water surface, provided one has a chart or charts showing the horizontal projection of the whole of that free water surface and the depth of the water at every point. This method and these fundamental constants were derived, originally, for use in the problem of determining the laws of evaporation from the Great Lakes. The importance of the method and constants will be much better appreciated, however, if one notes some of their many other possible applications.

When the dream of regulating the elevation of the Great Lakes by movable dams at certain of the outlets (St. Lawrence, Niagara, and St. Mary's Rivers) becomes a reality, as it certainly will in due time, it will then be important to watch the fluctuations of elevation of each lake with the highest attainable accuracy, in order to secure the best possible control. It will be important to correct the observed elevation at each recording gage, from day to day, for the effects of winds, in order to obtain true values of the mean lake elevation. Such necessary corrections are as great as 1 foot on rare occasions at Buffalo.

From the evidence derived from gages operated over long periods, or during widely separated years, at various points of Lake Michigan-Huron, the eminent geologist G. K. Gilbert determined that the whole region covered by this lake is slowly tilting to the southwestward, and secured a determination of the rate of tilting. This determination would obviously be strengthened if the corrections for wind effects at the gages were applied by using the method and constants now available.

Elevations determined by precise leveling are referred to mean sea-level by means of observations taken at tide gages. The mean sea-level as fixed by the observations at a given gage is in error by an amount dependent on the configuration of the shores and the bottom in the surrounding region and upon the prevailing winds. The method and constants now available will enable one to compute the necessary correction to be applied to the observed mean sea-level to eliminate the wind effect and so to obtain the true mean sea-level. Such a necessary correction may be small at certain gages. It is important to prove it to be small in such cases. The corrections are probably large enough at some gages to predominate over the accumulated errors in the precise leveling for hundreds of miles from the gages.

By carrying the theory one short step farther, from the fundamental constants here derived, one may compute approximately the surface current which is produced over the deep parts of the oceans by prevailing winds. One may so secure a valuable quantitative check on the extant theories as to the Gulf Stream, the Japan current, and the Equatorial currents.

These illustrations suffice to show that the method and constants will be valuable in a variety of engineering and scientific problems.

After accounting for the wind effects and barometric effects on Lake Erie, while studying the remaining fluctuations that were then unaccounted for, it became evident that the major portions of such short-period fluctuations (periods less than 24 hours) are the well-known seiches. These seiches are free oscillations of the lake surface with a natural period fixed by the dimensions and shape of the lake, persisting for a considerable time, with gradually diminishing amplitude, after a sudden disturbance of the lake surface due to a sudden change of wind or of barometric gradient.

At Buffalo, during the 22 days of observations which were intensively examined, there was one seiche, on October 27, 1910, with a period of 13.1 hours, which had a range of 3 feet during the first oscillation after the initial impulse which produced the seiche. At Cleveland, the same seiche in the first oscillation after the impulse had a range of 1.5 feet. A seiche of this 13.1-hour period is usually in progress at Buffalo and Cleveland. The range of oscillation is, however, usually very much smaller than in the extreme case quoted.

At Buffalo, the seiche periods of the prevailing seiches were found to be 13.1 and 3.7 hours.

The 13.1-hour seiche was identified as being an oscillation of the deep portion of Lake Erie as a whole, lengthwise, from the 10-fathom curve southwest of Buffalo near the east end of the lake to the vicinity of Cedar Point light-house off Sandusky. The portion of the lake extending about 40 miles west from Cedar Point is all rather shallow, less than 7 fathoms deep as a rule, whereas the parts to the eastward concerned primarily in the seiche are nearly all more than 10 fathoms deep. This 13.1-hour seiche prevails also at Cleveland and always differs in phase about 180° between Cleveland and Buffalo. That is, it is high water at Cleveland on this seiche when it is low water at Buffalo, and vice versa,

It is very probable that the seiche appearing frequently at Buffalo with a period of 3.7 hours is a free oscillation, lengthwise, of that deep part of Lake Erie which lies between the 10-fathom curve southwest of Buffalo and the constricted part of the lake southwest of the end of Long Point, where the lake-bottom slopes upward, relatively steeply, to the westward from depths of about 20 fathoms to depths of about 12 fathoms. This deep portion of the lake which is apparently oscillating as a unit is only about one-quarter of the total length of the lake.

At Cleveland, in addition to the seiche with a period of 13.1 hours which has already been noted as prevailing there, a seiche with a much shorter period, 2.6 hours, was also found as a rule. The evidence is reasonably clear that this short-period seiche at Cleveland is a deep-water oscillation, crosswise the lake, between the 10-fathom curve near Cleveland and the 10-fathom curve near the opposite part of the Canadian shore.

Howe, Henry M., Bedford Hills, New York. *Research Associate in Metallurgy.* (For previous reports see Year Books Nos. 6–18.)

Early in the present fiscal year I brought back to Bedford Hills, New York, my laboratory, which in 1918 had been moved to the U. S. Bureau of Standards, Washington, to facilitate the war work which I was then doing.

During most of this year I have been engaged in determining the limits of the conditions of thermal treatment which result in bringing steel into the sorbitic state, the most advantageous state for most engineering purposes.

Much new apparatus has had to be assembled for this purpose, and some of it has had to be designed. The conditions resulting from the war have retarded this work. The results are not yet ready for publication.

With Mr. F. B. Foley, and at the request of Professor C. E. Munroe, chairman of the committee on explosives investigations, National Research Council, I ascertained that the abundance of mechanical twins, called "Neumann bands," set up by explosion or impact in low-carbon steel, increases with the velocity of impact till this passes 2,296 meters per second, and is greater with 3,190 than with 2,296 meters. With further increase in velocity no further increase in abundance could be detected.

Nichols, E. L., Cornell University, Ithaca, New York. *Report on studies in luminescence.* (For previous reports by Dr. Nichols, see Year Books Nos. 4–18.)

FLUORESCENCE AT HIGH TEMPERATURES.

Since the recent completion of our monograph on the uranyl salts,[1] attention has been directed chiefly to luminescence at high temperatures. This is an entirely new field, it having hitherto been assumed that, with the discharge of thermo-luminescence at temperatures somewhat below the red heat, all luminescent activities vanish, very much as magnetization of iron ceases at the temperature of transformation.

We find, on the contrary, that many oxides, notably CaO, MgO, ZnO, ZrO_2, SiO_2, and Al_2O_3 are fluorescent throughout a much higher range of temperatures—roughly to an upper limit frequently lying between

[1]Fluorescence of the Uranyl Salts: E. L. Nichols and H. L. Howes, in collaboration with Ernest Merritt, D. T. Wilber, and Frances G. Wick, Carnegie Inst. Wash. Pub. No. 298, 1919.

600° and 1000° C. The effect is also present in many sulphides, particularly sidot blende (ZnS), Balmain's paint (CaS), and some of the phosphorescent sulphides of Lenard and Klatt. It is likewise found in various other compounds, such as calcium carbonate, cadmium phosphate, boric acid, telluric acid, and in crystals of calcite, fluorite, kunzite, synthetic ruby, etc.

Many preparations that are highly fluorescent at ordinary temperatures, such as calcium tungstate, artificial willemite, canary glass, didymium glass, etc., fail to respond to excitation at these high temperatures, and the oxides of iron, copper, cadmium, titanium, nickel, cobalt, barium, etc., are altogether inactive.

A New Source of Excitation.

This luminescence at high temperatures is not photo-luminescence—that is, it can not be produced by exposing the material, heated to the required temperature, either to the iron spark, the radiation from an electric arc, or to sunlight. The oxides mentioned above are not excited by light at any temperature, and the sulphides, which are powerfully photo-luminescent with persistent phosphorescence when cold, cease to be excited by light at much lower temperatures, as was abundantly established by Lenard and Klatt in 1904.

The glow is not merely a type of selective temperature radiation. Heating alone will not produce it. Excitation at these temperatures is obtained by contact with the hydrogen flame and we have called this new source of excitation *flame excitation*. It occurs only in a certain active zone within the flame along the boundary between reduction and oxidation. The powerful reducing action of the hydrogen flame seems to be essential, all other flames thus far tried being ineffective.

A full supply of free oxygen in the atmosphere is also necessary, it being possible to check the glow by a surrounding mantle of the fumes from a Bunsen burner or to enhance it by a gentle current of cold air.

The close relation of this effect to luminescence at ordinary temperatures is established by the following observations:

(1) The fluorescence is followed, after extinction of the flame, by phosphorescence which, in the only cases thus far studied, is of the vanishing type with the usual linear processes; total duration a few hundredths of a second.

(2) The spectrum does not correspond in distribution of intensities with that of temperature radiation, but consists of two or more broad, overlapping bands. These, as shown by detailed spectro-photometric measurements made upon calcium oxide and upon certain of the sulphides by Dr. H. L. Howes, are made up of numerous equidistant components identical with those belonging to the ordinary luminescence spectrum of the substance in question.

(3) Many, if not all, of the substances susceptible to flame-excitation fluoresce at the same temperatures under kathode bombardment, and when further heated the temperature at which they become inactive is the same for the two types of excitation.

(4) The luminescence spectrum under kathode excitation appears in general to be the same as for flame excitation.

(5) Many of the substances in question are excited by X-rays throughout the range of active temperatures.

Papers describing our preliminary observations on flame excitation, on the spectra of this high-temperature luminescence (by Professor Howes), and on the type of decay of phosphorescence (by Mr. Wilber) will be published shortly.

Since the annual report of 1919, papers have appeared on the uranyl acetates[1] and on the uranyl sulphates.[2]

Dr. Murdock's paper on photo-active cells covering his investigations of several years past is ready for publication.

The first of a series of papers by Dr. Howes on the kathodo-luminescence of the rare earths is in the press. His measurements of the fluorescence spectra show groups of very narrow bands arranged in constant-frequency intervals. The constitution of the spectrum, at least in the case of samarium, which forms the subject of this preliminary paper, is independent of the amount of the element in solid solution and of the heat treatment.

The rare earths used in these experiments are of extraordinary purity, being due to the kindness of Professor James, of New Hampshire College, who isolated them. The solid solutions were prepared by Dr. D. T. Wilber.

[1]Fluorescence and absorption of the uranyl acetates, Nichols, Howes, and Wick, Physical Review (2), xiv, 201.
[2]*Ibid.*, 293.

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